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CHEMOTAXIS OF OEDOGONIUM SPERMS

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ABSTRACT. Evidence has been obtained that female filaments of two heterothallic species of *Oedogonium* produce a substance or substances in conjunction with oogonium formation which chemotactically attracts sperms. Sterile female filaments do not produce this substance. These substances are specific for these two species. Crude preparations of these active substances were studied and some of their properties are reported.

Over a century has passed since N. Pringsheim (1858) first described sexuality in *Oedogonium*. Although others may have observed the sperm cells with their "crown" of flagella entering the oogonium to unite with the egg (Fig. 1), Ohashi's (1926, 1930) and Spessard's

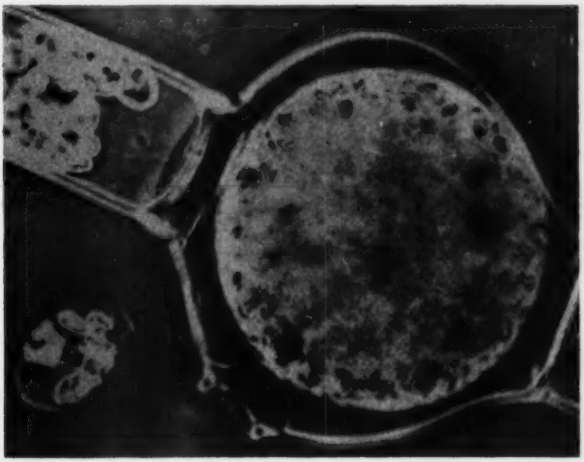

Fig. 1. *Oedogonium cardiacum*. Oogonium with mature egg and approaching sperm.

(1930) accounts are among the few reported in the literature. As yet, however, the mechanism involved in regulating sperm movements has not been resolved.

There are numerous reports in the literature of chemotaxis of sperms in a variety of plants. Various aspects of the phenomenon have been summarized by Raper (1952, 1957) and Rothchild (1956).

Pfeffer's (1884) classic work on the chemotaxis of fern sperms set the stage for later work. He, and more recently others (Rothchild, 1952 and Wilkie, 1954), found that various organic acids (e.g., L-malic) attracted fern sperms. Similar chemotactic movement of sperms has been demonstrated in various other vascular cryptogams (Rothchild, 1956).

Pascher (1931) reported chemotactic response of sperms in the green alga, *Sphaeroplea*. He placed a cotton thread in a mature female culture and then transferred it into a dish with sperms. The sperm cells remained clustered about the thread for one to two hours.

Förster and Wiese (1954, 1955) have demonstrated the production of extracellular substances which are involved in clumping in isogamous species of *Chlamydomonas*.

Work on *Fucus* has led to some conflicting reports, but the latest work by Cook et al. (1948) and Cook and Elvidge (1951) indicates that the substance (s?) causing chemotactic aggregation of sperms in *Fucus* is volatile and relatively stable; attempts at identification have yielded inconclusive results.

Recently, Machlis (1958a, 1958b, 1958c) has demonstrated, isolated, and characterized a hormone from the phycomycetous, heterogamous fungus, *Allomyces*, which produces a chemotactic response in the sperm cells.

Tiffany (1957) alludes to the chemotactic hormones in *Oedogonium* as follows:

"The behavior of both the sperm and the androspore suggests the formation of chemical substances (hormones), at least by the female cells, to which these flagellated cells respond."

"In view of the classic investigations of Raper on *Achlya* (a fungus) and other research on sexual aspects of algae and fungi, similar formations of sex hormones in the Oedogoniaceae seem probable. It is hoped that the techniques necessary to analyze the sexual behavior of sperms and androspores in the Oedogoniaceae, admittedly difficult, may be solved at an early date."

The present study of *Oedogonium* was undertaken to determine the nature of the mechanism that brings the sperm into contact with the egg.

The material used in this study was *Oedogonium cardiacum* Wittr. (Indiana Culture Collection #39 and #40) and an unidentified species collected and cultured by the author. Both species are heterothallic, and the male and female clones are maintained separately in

soil-water culture (Pringsheim, 1949). The sexual stages can be obtained at will.

Two procedures have been used to study chemotactically active substances thought to diffuse into the medium from their site of production in fertile female plants. In the first, a homogenate of the fertile female filaments was used. A second procedure consisted of inducing female filaments, repeatedly rinsed in distilled water, to form oogonia in distilled water. Then, 4–8 days after the oogonia had begun to form, the fluid (distilled water) was concentrated by evaporation. The yield seems to be somewhat less by this second method, but the sample is less contaminated than those prepared by homogenation. Extractions of the concentrates prepared by both procedures with either chloroform or ether, made either acid or basic, resulted always in the recovery of the active substance (s?) in the water fraction.

Numerous methods of assaying the extracts have been tried. Two proved especially useful. In the first, fine capillary tubes were prepared from soft glass tubing; the extract to be assayed was drawn into the tube by capillarity. The tube was then broken into ¾-inch sections and one was placed carefully with a fine forceps into a suspension of sperms.

With these procedures, the tube containing the active substance (s?) begins to attract the sperms quite rapidly, and, after a minute, the sperms cluster about its mouth. More and more sperms are gradually attracted and begin to enter, and move up, the capillary tube (Fig. 2).

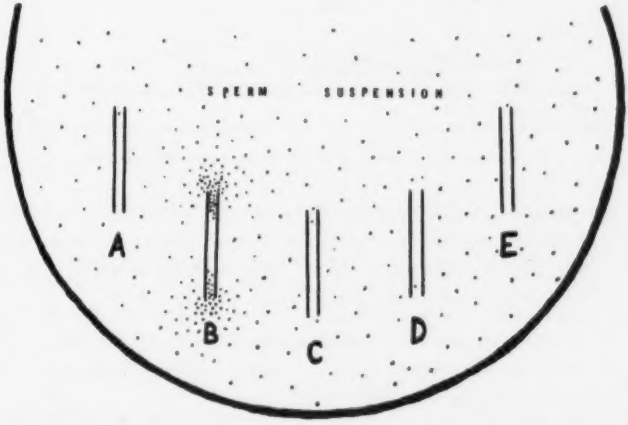

Fig. 2. *Oedogonium cardiacum*. Diagrammatic representation of activity: A. Distilled water; B. Preparation from oogonium-bearing filaments; C. Preparation from sterile female filaments; D. Soil-water supernatant; E. Bacto-nutrient broth. Dots represent sperms.

Control tubes containing extracts from sterile female filaments, soil-water extract, distilled water, and various inorganic and organic media do not attract the sperms. Zoospores are not attracted by the same substances which affect the sperms.

The second method (Cook et al., 1948) differs from the first in that a 1% agar plug is placed within the mouth of an L-shaped capillary tube. The extract is placed in the upright arm of the "L" and brought up to a level above that to which capillarity would normally draw the fluid. The tube is mounted upright on a microscope slide with the agar-plugged end in a drop of sperm suspension. Results of this second method of assay are similar to those obtained with the first. Sperms are attracted by the active substance (s?) as it diffuses through the agar to the mouth of the tube (Fig. 3).

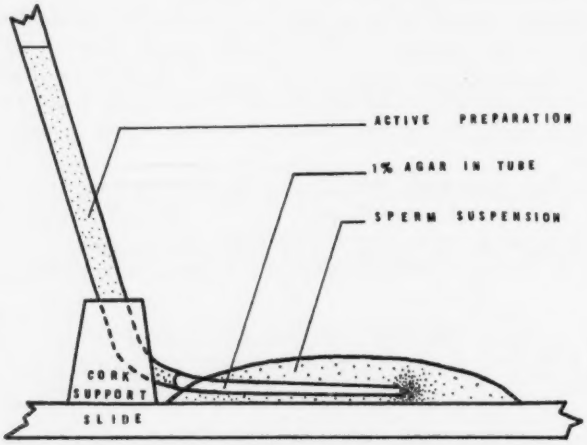

Fig. 3. Agar-plug method of bioassay. Dots represent sperms.

The properties so far recorded for the chemotactically active substances involved in attraction of *Oedogonium* sperms are summarized below. The active substances from both species investigated were similar in character, except in the instance cited.

1. Activity was always associated with the water fraction in the extractions with ether (acid or basic), with chloroform (acid or basic), and with hot, 80% ethyl alcohol.
2. Some activity remained after boiling preparations of active substances for 15 minutes. Major loss of activity resulted when they were autoclaved 15 minutes at 15 lbs. pressure.

3. Some activity remained after treatment with 4.0 N HCl and evaporation to dryness.
4. Preparations are stable, as both Seitz-filtered and non-filtered samples have been maintained frozen for 7 months with no apparent loss of activity.
5. An active fraction passed through a dialysis membrane could be recovered in the distilled water outside the membrane.
6. Attempts at chromatography have not been satisfactory, but active eluates have been recovered from the chromatograms.
7. The active substance (s?) of one species did not attract the sperms of the other, and vice-versa.

Ionic (or non-ionic) properties have not been ascertained, nor has a standard been devised by which different concentrations of the substance (s?) can be distinguished.

The author hopes to further purify and characterize the chemotactically active substances herein reported. Bacteria-free cultures are a necessary prerequisite for further work. Preparations from other species of *Oedogonium*, which the author now has in culture, will be studied in similar fashion.

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A PRELIMINARY STUDY OF THE SHINNERY IN OKLAHOMA

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ABSTRACT. Shinnery is scattered throughout the western third of Oklahoma principally on coarse soils derived from materials of the Pliocene and Pleistocene epochs. It occurs on sandy soils (Brownfield and Nobscott series) throughout the mixed prairie and short grass plains in a region of low precipitation (20 in. to 25 in.). The most common species is *Quercus Havardi*, although *Q. stellata*, *Q. Margaretta* and *Q. Mohriana* are present. The shinnery constitutes an oak population of extreme hybridity with *Q. Havardi* x *Q.* stellata being the most common hybrids. Most stands of shinnery are two to four feet high, although the height may vary from one to 40 feet. Since no germination of acorns was observed, it is assumed that reproduction is accomplished largely by rhizomes. Fire is utilized to control the height of the shin oaks and to promote an increase in forage whereas the herbicide, 2,4,5-T, when used for three successive years, eliminates much of the shinnery.

Early explorers in western Oklahoma commented on areas of dwarf oaks and several shrubs, variously designated as chaparral, shin oak or shinnery (Gregg, 1839; Marcy, 1853 and others). The term "shinnery," which is employed in this discussion, is derived from the French word "cheniere." Shinnery does not refer to dwarf oaks which are about shin-high as is generally believed. Shinnery is a vegetation type which comprises diminutive oaks (shin oaks) from two to four feet tall with islands (mottes), of the same shin oak species, up to twenty feet above the general level of the stand (Fig. 1).

In his report on 'The Vegetation of Oklahoma', Bruner (1931) states that the chaparral ". . . is represented in the central part of western Oklahoma by communities of the 'shin oak'." According to Bruner, the shin oaks include "*Quercus mohriana*, *Q. stellata palmeri*, *Q. stellata rufescens*, and *Q. vaseyana* . . ." In addition, the shinnery often comprises *Artemisia filifolia*, *Rhus trilobata*, *Celtis reticulata*, *Cornus drummondii*, and *Prunus angustifolia*. According to Duck and Fletcher (1948) a total of 1173 square miles of the shinnery-grassland type occurs in western Oklahoma, principally in Woodward, Ellis, Roger Mills, Beckham, and Harmon Counties.

This study was limited to Oklahoma only. It includes the area from

* Nomenclature follows Waterfall's catalogue of the flora of Oklahoma.

Fig. 1. Mottes of shin oak protrude from five to twenty feet above the general level of the shinnery.

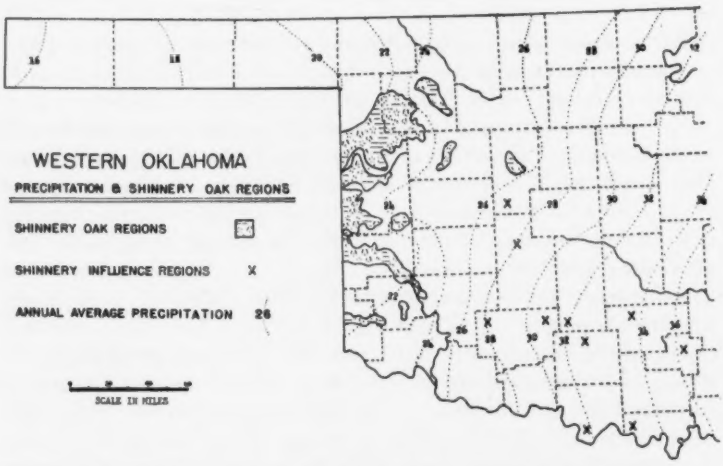

Fig. 2. Map showing isohyets, stands of shinnery and areas of shin oak influence.

below the Salt Fork of the Red River in southwestern Oklahoma to a point above the North Canadian (Beaver) River and from the western border of Oklahoma to about 98° 30′ west longitude (Fig. 2). Shinnery was observed in Jackson, Harmon, Greer, Beckham, Roger Mills, Ellis,

Dewey, Woodward and Blaine Counties. In addition, there was evidence of introgression of certain shin oak species (as indicated by leaf and fruit characters) in Major, Custer, Caddo, Comanche, Grady, Stephens, Jefferson and even as far east as Murray and Love Counties (Fig. 2).

The shinnery region is characterized by a continental climate, with hot summers and moderate winters. It is noted for extremes in temperature, unreliability of moisture, high winds, and occasional dust storms, blizzards and tornadoes. The mean monthly minimum temperature (January) range from 35° F in the north to about 40° F. along the southern border. The mean maximum temperature (July) varies from about 81° F. to about 86° F. More important is the paucity (20 inches to 25 inches) and unreliability of the precipitation (U.S. Weather Bureau, 1957).

Shinnery occurs on sandy soils derived from materials of the Tertiary and Quaternary periods. Pliocene deposits are present in Ellis, Roger Mills and Woodward Counties. The high terrace deposits and dune sands of the Pleistocene are located chiefly in Harmon, Beckham, Blaine, Dewey and Woodward Counties. Some shinnery also occurs on dune sands of recent origin, especially in river bottoms and along the north sides of rivers. The shinnery is characteristic of sandy soils in the mixed prairie and the short grass plains. It occurs also in the sandsage-grassland area and to a less extent in the tall grass prairie and blackjack-post oak regions.

The shinnery is found chiefly on the Brownfield and Nobscott soil series. It exhibits greater size and taller mottes in the Brownfield series than in the Nobscott soils. An interesting feature of the soils in the taller mottes is a lower pH value and an approximation of a forest soil type, although the rainfall is less than 25 inches. Occasional areas of shinnery are found in the Miles series which is a reddish fine sandy loam. This is unusual since shin oaks do not regularly occur where there is much calcium carbonate in the soil. Such an example may be seen about nine miles north of Cheyenne in Roger Mills County. A second example may be observed on top of the Antelope Hills, where dwarf shinnery occurs on sandstone which is impregnated with calcium carbonate.

Much of the work on the taxonomy of the shin oaks has been done by C. H. Muller (Muller, 1951, 1952). Several workers concluded that the major species of shin oak was *Quercus Havardi*, named after Dr. Valery Havard by Rydberg (1901). According to Dr. Muller, who kindly identified our specimens, associated species included *Q. stellata*, *Q. Margaretta* and *Q. Mohriana*. Most of the hybrids he listed were derived from *Q. Havardi* and *Q. stellata*.

The diminutive oaks of the shinnery constitute a population of extreme hybridity. The leaves, stems, buds, acorn cups and acorns vary widely in color, shape, size, and pubescence. Before the identifications were received from Dr. Muller, we attempted to delineate the various taxa in the shinnery. Obviously different forms were compared for sixteen characters on leaves, stems, buds, cups, and acorns. Two or three variations of each character were punched on McBee Keysort cards. Combinations of specific characters were then made by spindling the Keysort cards. Although our investigation was not as complete as desired, it appeared that there was no specific correlation between any of the different forms. We concluded, therefore, that there were no definitive taxa with readily recognizable characters. It seems probable that there are many specimens that are definitely referable to *Quercus Havardi*, *Q. stellata*, *Q. Margaretta* and *Q. Mohriana*. However, the study of our specimens did not lead to such a conclusion.

With reference to hybridity, Muller (1951) states that "In comparatively ancient times there existed a wide contact between *Quercus Havardi* and the more easterly *Quercus stellata*, both of which are arenophilous species. . . . Along the 'breaks' of the Plains *Quercus Havardi* comes in contact with *Quercus Mohriana* quite extensively and there results some degree of hybridization and consequent confusion." Concerning the mottes, Muller (1951) wrote that "The prominences (mottes) are plants exhibiting more or less evidence of hybridity with *Quercus stellata* . . ." This statement is true for many of the mottes. However, some of the mottes, including the taller ones, exhibited leaf characters far different from those of *Quercus stellata*.

The most common woody species which are associated with shin oaks are sandsage (*Artemisia filifolia*), skunkbrush (*Rhus aromatica* var. *pilosissima*), western hackberry (*Celtis reticulata*), yucca (*Yucca glauca*), and grapes (*Vitis spp.*). Along the eastern border of the shinnery the common associates are post oak (*Quercus stellata*), blackjack (*Q. marilandica*), and eastern red cedar (*Juniperus virginiana*).

The major grasses in the shinnery comprise little bluestem (*Andropogon scoparius*), triple-awn grasses (*Aristida spp.*), hairy grama (*Bouteloua hirsuta*), blue grama (*B. gracilis*), sandburs (*Cenchrus* spp.), and sand drop-seed (*Sporobolus cryptandrus*).

Shin oaks vary in height from about one foot on top of the Antelope Hills, Roger Mills County, to about 40 feet in Boiling Springs State Park, Woodward County. Most of the stands range in height from two to four feet, with occasional mottes up to 15 feet (Fig. 1). The shin oak grows from one foot to two feet during the first year, and attains a height of about four feet in eight years. Since ranchers burn the range

regularly it is assumed that the usual height (two to four feet) is governed largely by fire.

The growth rate of shin oaks vary with soil type, rainfall and soil moisture. In Ellis County the annual increase in diameter was only 1.1 mm/year. In Woodward County, the annual increase was 4.8 mm/year and in Harmon County, the annual diameter increment was 5.2 mm/year. It is probable that these figures are only approximate since data were obtained from only 65 plants. It is obvious, however, that a considerable difference in growth rate does exist.

Information on subterranean parts was obtained from a study of recent road cuts and diggings in the mottes. Apparently the roots penetrate deeply and do not branch much until the B_2 horizon is reached at a level from 25 to 50 inches below the surface. The rhizomes develop from young plants, at a depth of one to two feet, and produce new erect shoots if the original aerial parts are destroyed. In mottes ten feet or more in height the rhizomes apparently decay. The shin oak reproduces readily by rhizomes, occasionally by coppice and probably rarely by acorns. No germination of acorns was observed during the course of our study. It is possible, however, that in years of exceptional acorn crops, considerable reproduction by acorns might occur.

Grazing and fire appear to be the most important factors under man's control. Grazing lowers the combustible material, reduces the herbaceous competition for the shin oaks, and thus favors the growth of shinnery. Since the opening buds and young leaves of the shin oaks are poisonous to cattle, the ranchers are interested in eliminating them.

Periodic fires are common throughout the shinnery region. If the fires are hot enough all of the above ground parts are destroyed. In such cases, new shoots are produced by the rhizomes. These fires result in thickening the stand as well as reducing the height of the oaks so that the grasses are not shaded out. Fires also decrease the shrub cover so that livestock can graze throughout the area. Fire does not burn through the taller mottes because of the lack of sufficient combustible material to carry the fire. Apparently the formation of mottes is related to chance protection from fire of a small portion of the shinnery at an early age. As the height of the shin oaks in the area increases the amount of herbaceous vegetation diminishes with the result that the chance of fire decreases with the height of the motte.

Although fire is still used to increase the grazing potentialities of the shinnery, the use of formagenic herbicides is increasing in importance. Workers at the U. S. Southern Great Plains Field Station have been experimenting with 2,4-D, 2,4,5-T, and 2(2,4,5-TP) (McIlvain and Armstrong, 1958). Use of 2,4,5-T early in the spring at a rate of one

pound per acre, applied for three successive years, reduced the shinnery by 90 percent. This treatment also destroyed 95 percent of the sandsage, skunkbrush, and sand plum (McIlvain and Armstrong, 1958).

ACKNOWLEDGMENTS

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DOMINANCE SHIFTS IN THE TREE LIZARD (*UROSAURUS ORNATUS*—IGUANIDAE)

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ABSTRACT. The social activity of tree lizards *(Urosaurus ornatus)* observed in an enclosure included display, push-ups, courtship, chasing, fighting, retreat and submission. After preliminary aggressive interactions, one male achieved dominance and thereafter accounted for the majority of all social activity in the group. Removing or replacing a dominant male in the group effected shifts in the dominance pattern. Dominant males were darker in color.

This study is part of a project comparing the behavior of iguanid lizards of the United States supported by the National Science Foundation. All observations were made on a population of tree lizards (*Urosaurus ornatus*) maintained at the University of Oklahoma Biological Station in south central Oklahoma during the summer of 1959. These tree lizards were obtained the previous April from the live oak-savannah association at the base of the south side of the Huachuca Mountains in southeastern Arizona. The lizards were confined in a square sheet metal enclosure measuring 10 feet on a side and three feet in height. The bottom of the enclosure was covered with sand with a high mound in the center. Small logs and hollow concrete building blocks (piled two high) were spaced about two feet apart throughout the habitat. Other species in this enclosure included species of the genera *Uta*, *Holbrookia*, *Callisaurus*, *Sceloporus*, *Phrynosoma*, and *Cnemidophorus*.

Six males and two female *Urosaurus ornatus*, color marked for individual recognition, were placed in this enclosure on June 6 and were observed on thirty different days until August 14. Observations were confined primarily to peak activity periods in late morning and late afternoon, and were recorded on tape, which enabled continuous, uninterrupted observation. Social activity was observed within minutes after the lizards were placed in the enclosure, which included display, push-ups, courtships, chasing, fighting, retreat and submission. Display involved lateral compression of the body and extension of the dewlap (both dimorphically colored in the male) accompanied by push-ups in a specific sequence (Carpenter and Grubitz, *Ecology*, in press), with the performing individual presented laterally towards his adversary. This display, which was sometimes accompanied by chasing and fight-

ing, was the apparent means by which a dominant-subordinate relationship was established between particular individuals within the group. Push-ups were frequently performed unaccompanied by lateral compression and dewlap extension by both males and females. In courtship, the male responded to the presence of a female by rapidly nodding h's head. Subordinate behavior involved a retreat or flight away from, or a submissive posture (remaining motionless and flattened out), in response to a dominant lizard which may or may not have displayed.

Displaying, push-ups, courting, chasing and fighting, were all considered aggressive actions contributing to dominance, while retreat, loss of a fight and submissive posture indicated subordination.

The display activity was carried on by the males and was generally confined to one or two of the more aggressive males. All males and females performed push-ups at some time. The accompanying figure illustrates the activities described below.

For the first week of observations, two of the six males were more active than the other four. Of these two (white and red), the white male was recorded as being the more active (displaying and performing more push-ups) and by June 20, completely dominated all activity. The red male displayed only occasionally.

On the morning of June 20, the white male was removed from the enclosure. During the rest of this day, the activity of the red male increased (displaying and courting females), and no other males were observed to display. During the succeeding week, the red male continued to be very active, displaying frequently in contrast to the relative inactivity of the other males. The red male was very aggressive toward the green male, defeating him in a fight and frequently the green male showed a submissive posture by flattening out motionless when the red male displayed.

Having determined that the red male was dominant, I returned the white male to the enclosure on June 30. At this time the present dominant red male was very dark in color, in contrast to the white male and the other males in the enclosure. Within one minute of the reintroduction of the white male, the red male and the white male were vigorously displaying at one another. The white male gave ground to the darker red male and finally retreated. The red male also approached and displayed at the green male, which fled with the red male in pursuit.

The red male continued to be the most active male, displaying frequently and chasing the other males, while courting the females. The red male was much darker than the other males. By July 15, the dis-

playing of the red male had increased, his displays being as frequent as 48 times in one hour. Frequently other males would flee at the sight of the red male.

The red male (now the dominant) was removed from the enclosure on July 22. On July 24, the green male had become dark in color and was the most active individual, displaying frequently. At this time the green male was chased around the enclosure by the observer for two or three minutes with the apparent result that he became lighter in color. The green male was dominant over the next week, displaying frequently and chasing the other males.

On July 30, the red male (light in color) was returned to the enclosure where the green male (dark in color) was now dominant. During this day, there were many interactions between the green male and the red male. In the first encounters, the green male appeared to win because the red male retreated away from his challenge. Both the red male and the green male vigorously challenged and chased the other subordinate males. On returning to observe them in late afternoon, the green male had become lighter in color, the red male darker. The red male was the more active, displaying at the green male which did not display in return to these challenges.

By August 3, the red male dominated all activity (displaying and courting the females) and no other males were observed to display during the following four days. On August 8, the red male was removed from the enclosure. While he was being held temporarily in a gallon jar, he began to turn lighter in color. The other males left in the enclosure were light in color when the red male was removed. These males increased their activity but did not display at each other. Approximately one hour later, the green male displayed. The green male became more active during the day than the other males, displaying at and chasing them, though the orange male did display.

On August 9, the green male was darker in color and displayed frequently. The other males were visible and active, but did not display. By August 10, the green male had become fully dominant, challenging and chasing other males.

On August 11, the green male was removed from the enclosure (both red and green now removed). The other males became more noticeably active, the grey male in particular. Within one and one-half hours, the grey male appeared to be darker in color, and by late afternoon he was very dark, actively displaying at and chasing other males, and moving over the entire enclosure. The next day this activity continued, the now dominant grey male aggressively challenging and chasing the white and other males, and also courting the black and orange females.

The red and the green males were replaced in the enclosure at 9:00 a.m. on August 13. Within one minute, the red and green males had moved to raised objects, and the red male began to display. The white male had become dark and was displaying. The green male responded to the displaying of the grey male by displaying back. They both approached one another, laterally presented until six inches apart, then struck at one another twice; the grey male retreated slightly, the green male held its ground. The green male again approached the grey male, and this time the grey male retreated. The grey male moved to a high point, displayed, and immediately the red male responded with a display. All four males were now displaying, or performing push-ups. The red male retreated from the displays and approaches of the green male and the white male. The grey male returned the display challenge of the green male and the red male returned the display challenge of the green male who was on an object above him by tipping his body up towards the green male while displaying. The red and the green males continued to display at one another. By 10:15 a.m. the challenging activity had resolved itself to the green and the red male. The two males repeatedly displayed at one another, though remaining apart, moving from one raised object to another. The green male (slightly darker in color) moved to the object on which the red male was displaying, and the red male fled to a small log and then displayed. The green male moved towards the orange male, and the latter fled immediately. All other males were now fleeing from the approaches of the red and the green male. The red and the green male continued to display frequently at one another, though remaining distant from one another.

By late afternoon the red male had become very dark in color and was observed courting the black female. The green male fled from the display of the red male; the red male now appeared to be dominant again. The green male had become lighter in color and was much less active and not displaying. On August 14, the last day these lizards were observed, the red male appeared to be completely dominant over the other males. He was much darker in color than the other males and was observed displaying at the green and the grey males, causing them to flee. No other males were observed displaying.

The above observations indicated that when a particular male had become dominant, he was responsible for almost all aggressive activity, so much so, that only rarely did other males perform push-ups or court females. The subordinate males were usually so dominated that they would retreat to cover from the presence of the displaying dominant male, or would assume a submissive posture in his presence. The subordinated males kept their distance from the dominant male and much

of the time were inactive and out of sight. If visible, they did not perform push-ups.

The females appeared to be little disturbed by the aggressive actions of the males. Only rarely did they retreat and they readily performed their less intense push-ups in the presence of the dominant male.

Obvious color changes occurred in lizards as they attained dominance or lost this dominance and became subordinate. The lizard which had established its dominance was always very dark brown in dorsal coloration. In contrast, subordinate males were usually light brown in dorsal color. When a dominant was removed from the enclosure and isolated, it became lighter in color in about one to two hours. When this lizard, still light in color, was later returned to the enclosure, it began to turn darker if it became aggressive, and maintained this dark color if it became dominant. If it did not become dominant, but was forced to retreat and become subordinate, it again became light and remained this way. Whether or not this darkening in color enhanced the dominant's ability to maintain this status, was not tested. The darkening seemed to occur as the lizards became dominant, and thus might be the result of dominance, rather than an aid to attaining it. Two instances cited above, the male turning lighter in a bottle soon after removal, and a male turning lighter after being chased around the habitat by the observer, lend support to the idea that the dark or light color is related to, or is a result of, the psychological state of the lizard. No noticeable change in color was recorded for the females.

The dominance appears to be dependent upon individual size in the group observed. The red male was the largest, the white male second, the green third, orange fourth, grey fifth, and yellow sixth. The white male, second largest, was the first dominant, but was replaced by the larger red male and did not become dominant again in the absence of the red male. Further study will be necessary to substantiate this dominance-size relationship.

In summary, dominance in male tree lizards is determined by aggressive activity. The male which displays frequently and is able to bluff his opponent or win over him in combat consistently becomes the dominant. In this group the largest males were dominant. This state of dominance is accompanied by darkening in color. When dominance has been established, the other male lizards are much less active, tending to avoid the presence of the dominant, and they are much lighter in color. The dominant male does most of the courting of the females. Shifts in dominance from one male to another can be effected by removal of the dominant(s) from the group, and return of a previously

dominant male to the group. In nature, this aggressive behavior and dominance would be associated with the establishing and maintaining of a territory by the male.

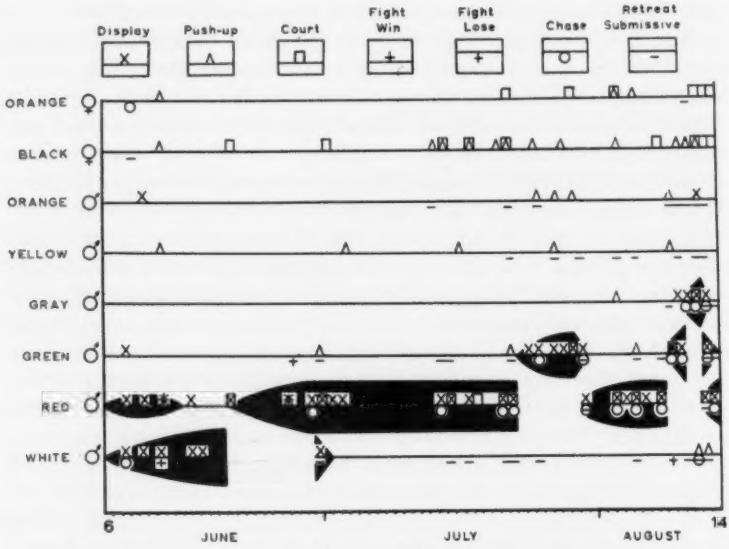

Fig. 1. Diagram depicting social activities as related to dominance and shifts in dominance in a group of tree lizards (*Urosaurus ornatus*). Symbols indicate a particular type of activity that was performed once or more on a particular day. Shading indicates the dominant lizard for that period of time. Discontinued areas in the line indicate that individual has been removed from the group for that period of time.

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MATING CALL AS EVIDENCE OF RELATIONS IN THE *HYLA EXIMIA* GROUP[1]

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ABSTRACT. Sound spectrograms have been used to compare mating calls of five of the six species previously allocated to the *Hyla eximia* group of treefrogs and various other species. *Hyla euphorbiacea* Günther has such a different call as to cast doubts on its affinity with this group. The name *H. eximia* as it has been used apparently encompasses two morphologically cryptic species that differ strongly in pulse rate of the call. Only the slower-calling of these has been recorded from near the type locality. Fast-calling "*eximia*" from Michoacan have calls very similar to those of *H. wrightorum*. Whether or not the two are conspecific remains to be determined. The structure of the calls of *H. squirella* of the southeastern United States and the Mexican *H. staufferi* suggests that the affinities of these species lie with the *eximia* group.

INTRODUCTION

Mating calls of the relict *Hyla wrightorum* of Arizona were unavailable when we arranged most U. S. species of *Hyla* in species groups based in considerable part on call (Blair, 1959). Recorded calls of this species as well as those of related Mexican species have since been obtained and form the basis for this report.

Hyla wrightorum was described by Taylor (1938) as a member of the "*eximia* group", which has a center of distribution in southern Mexico. Schmidt (1953) listed *wrightorum* as a subspecies of *H. eximia*. Comparisons of mating calls provide information as to limits of the *eximia* group and as to the relationships within it.

Taylor (1938) listed six species in his *Hyla eximia* group, including *Hyla eximia* Baird, *Hyla euphorbiacea* Günther, *Hyla cardenasi* Taylor, *Hyla lafrentzi* Mertens and Wolterstorff, *Hyla regilla* Baird and Girard, and *Hyla wrightorum* Taylor.

ANALYSIS OF CALLS

Recordings of calls of *H. wrightorum* were made by M. J. Littlejohn, W. H. McAlister and myself in June, 1958. Recordings of the Mexican species were made in June, 1958, by R. W. Axtell, and in June and July, 1959, by M. J. Fouquette and A. C. Collins. Comparisons are made by use of sound spectrograms.

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HYLA WRIGHTORUM. Five individuals were recorded on the nights of of June 12 and 13, 1958, in Apache County, Arizona. Three were recorded in the outskirts of McNary. The other two were recorded on successive nights about 3.3 miles east of the Bog Creek Camp Ground on State Highway 73.

Significant measurements of these calls are shown in Table 1. The

TABLE 1

Mating calls of some members of the Hyla eximia *group as indicated by structure of the calls.*

Species and Locality	N	Temp. Air	Temp. H_2O	Mean Dominant Frequency (cps)	Mean Pulses /sec.	Mean Duration (sec.)
wrightorum						
Ariz.-Apache Co.- Bog Cr.	1	6.0	14.0	2000–2100	110	.17
Ariz.-Apache Co.-Bog Cr.	1	12.7	19.0	1900–2200	100	.15
Ariz.-Apache Co.-McNary	3	16.0	19.0	2020–2180	110	.16
"Slow *eximia*"						
Tlaxcla-Sanctorium	3	16.0	15.0	2315–2750	51	.31
Morelos-Amayuca	4	20.0	21.0	2840–2900	43	.19
Mexico-Nueva Ixtapan	8	19.5	21.0	2540–2870	41	.22
Mexico-Nueva Ixtapan	3	20.0	22.0	2535–2885	42	.19
Jalisco-Magdelena	1	20.0	23.0	2900–3800	53	.15
"Fast *eximia*"						
Michoacan-Zamora	2	.....	.....	2300–3000	110	.19
Michoacan-Jiquilpan	1	18.0	22.0	2700–3100	136	.15
Michoacan-Jiquilpan	1	18.0	22.0	2350–2750	123	.19
"Intermediate *eximia*"						
Michoacan-Patzcuaro	2	14.5	18.0	2375–2975	84	.23
lafrentzi						
Tlaxcla-Sanctorium	1	16.0	15.0	1600–2200	90	.69
staufferi						
Chiapas-Cintalapa	3	.....	.....	3130–3660	108	.19
Oaxaca-Tehuantepec	2	28.0	29.0	3825–4200	138	.16
Oaxaca-Acayucan	1	24.5	25.5	3400–4000	116	.18
Veracruz-Cordoba	3	24.5	24.0	3600–3600	100	.22
Tamaulipas-Monte	3	26.0	27.5	3215–3665	112	.16

call is very similar to that described earlier for *Hyla squirella* by Blair (1959), and as illustrated in Table 2. The call is rapidly pulsed, in excess of 100 pulses/second in both, and the duration is similar although slightly longer in *squirella*. There is a pattern of harmonically related emphasized bands with a rising frequency superimposed on the basic harmonic pattern as in *squirella*. As may be seen from Tables 1 and 2, the dominant frequency is lower in *wrightorum* than in *squirella* by several hundred cycles per second.

HYLA EXIMIA. Two kinds of calls have been recorded for frogs that morphologically fit the name *Hyla exiamia*. The difference is prin-

TABLE 2

Mating calls of Hyla squirella.

Locality	N	Temp.° C Air	Temp.° C H_2O	Mean Dominant Frequency (cps)	Mean Pulses /sec.	Mean Duration (sec.)
Florida-Levy Co.-Otter Cr.	1	23.0	25.0	3200–3650	110	.22
Florida-Alachua Co.-Hogtown Sink	3	24.0	26.5	2850–3430	127	.21
Florida-Putnam Co.-Welaka	8	25.0	26.5	3010–3550	111	.24
Miss.-Hancock Co.-Bay St. Louis	1	23.0	25.0	2650–3000	120	.23
Miss.-Perry Co.-Beaumont	5	24.0	25.5	2730–3310	110	.24
La.-Livingston Par.-Walker	1	25.0	25.0	2900–3700	120	.19
Tex.-Hardin Co.-Honey Island	1	21.0	21.5	2750–3450	90	.28
Tex.-Chambers Co.-Wallisville	1	21.5	22.0	2800–3100	100	.21
Tex.-Harris Co.-Lake Houston	2	28.0	28.0	3200–3900	120	.19
Tex.-Matagorda Co.-Markham	1	26.5	26.0	3100–3100	110	.21

cipally one involving pulse rate, for in one type the rate is usually less than 50 pulses/second while in the other it is usually in excess of 100 pulses/second (Table 1.). This situation apparently parallels the one in *Hyla versicolor* (Blair, 1958a; Johnson, 1959) where cryptic species are readily recognizable only on the basis of call difference.

Slow-calling *eximia* have been recorded at five stations in four Mexican states. Station data are as follows: *Jalisco*, 2.8 miles northwest of Magdalena; July 30, 1959, by Fouquette and Collins. *Mexico*, eastern edge of Nueva Ixtapan, elev. 6000 feet; July 26, 1959, by Fouquette and Collins. *Mexico*, 3 miles north of Nueva Ixtapan; July 26, 1959, by Fouquette and Collins. *Morelos*, 1 mile northwest of Amayuca, elev. about 4800 feet, in flooded rice paddies; June 21, 1958, by Axtell. *Tlaxcala*, 3 miles northwest of Sanctorium, elev. about 9000 feet, in rainpool in open field of agave plantation; June 9, 1958, by Axtell.

Fast-calling frogs of the *eximia* type have been recorded from three stations in the state of Michoacan. Station data are as follows: *Michoacan*, 2 miles southeast of Zamora, elev. about 6500 feet, roadside pool on high central plain; June 25, 1958, by Axtell; 5.4 miles northeast of Jiquilpan, elev. about 5200 feet; July 28, 1959, by Fouquette and Collins; 5 miles east of Jiquilpan; July 28, 1959, by Fouquette and Collins.

Calls of both the fast and slow type are of the same basic pattern as those of *squirella* and *wrightorum*, although there is some modification

in some calls at all of the fast-call stations. The calls of an individual may vary from one that is virtually indistinguishable from calls of the two U. S. species in structure through calls that show an accentuated terminal note that dips in frequency to one in which the sharply tuned terminal note both rises and falls in frequency (Fig. 1). Calls of two individuals recorded by Fouquette and Collins about 2 miles northeast

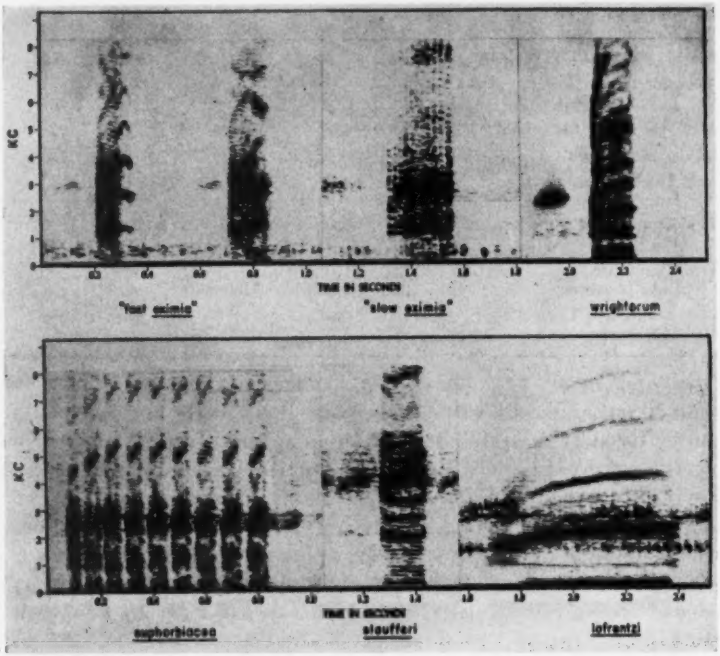

Fig. 1. Sound spectrograms of single calls of six kinds of *Hyla* belonging or possibly belonging to the *H. eximia* group: (1) two variants of fast-calling "eximia" from vicinity of Jiquilpan, Michoacan, Mexico, (2) slow-calling "*eximia*" from Nueva Ixtapan, Mexico, (3) *wrightorum* from vicinity of McNary, Apache County, Arizona, (4) *euphorbiacea* from vicinity of Tlacolula, Oaxaca, Mexico, (5) *staufferi* from vicinity of Tehauntepec, Oaxaca, Mexico, (6) *lafrentzi* from vicinity of Sanctorium, Tlaxcala, Mexico. Background sounds noticeable in all.

of Patzcuaro, Michoacan, at an elevation of about 6700 feet on July 27, 1959, are somewhat intermediate between the fast and slow groups, with pulse rates of respectively 80 and 87/second. The position of these individuals is not completely clear, but the fact that their rate averages closer to that of the fast group and the fact that the lower temperature at which they were recorded probably accounts in part at least for

the slower pulse rate lead to the conclusion that they belong with the fast-calling group.

HYLA EUPHORBIACEA. Calls of a series of frogs that fit morphologically in the *eximia* group were recorded by Fouquette and Collins about 2.4 miles south of Tlacolula, Oaxaca, at an elevation of about 5400 feet on July 19, 1959. Preserved specimens and one individual that remains alive fit Taylor's (1938) redescription of *Hyla euphorbiacea* Günther and key out readily to this species in Smith and Taylor's (1948) key. Taylor (1938) quoted Hobart Smith's diary to the effect that, "This hyla has a different call from *H. eximia*." This observation is borne out by the recorded calls, which differ so much from those of *eximia* as to raise the question of the relationship of this form to the *eximia* group. The call is very much like that of *H. baudini* and *H. arenicolor* of the *versicolor* group of Blair (1959). Among seven individuals recorded, the mean duration ranges from 0.41 to 0.75 second, and the mean of the means is 0.56.The call consists of a series of pulse notes, given at a rate of about 12 pulses/second. The dominant frequency in the seven individuals ranges from 2150 cps to 2450 and averages 2340. As in the above mentioned members of the *versicolor* group, there is no appreciable change in dominant frequency in the course of the call.

HYLA LAFRENTZI. One frog that fits the description by *Hyla lafrentzi* Mertens and Wolterstorff as given by Taylor (1938) was recorded by Axtell about 3 miles northwest of Sanctorium, Tlaxcala, at an elevation of about 9000 feet, on June 9, 1958. This frog was recorded in a rainpool in open fields of an agave plantation, where slow-calling *eximia* were also recorded.

The call of this frog is of the basic *eximia*-group type (Table 1; Fig. 1) but differs principally in its greater duration, being three to four times as long as in *eximia*. The pulse rate at 90 pulses/second is a little slower than that in fast-calling *eximia*.

HYLA SQUIRELLA. The mating calls of *H. squirella* have been previously described and figured (Blair, 1958b, 1959). Measurements of presently available calls are given in Table 2. The calls of this species are very similar to those of *wrightorum*, fast-calling *eximia*, and *staufferi*.

HYLA STAUFFERI. Frogs fitting the description of *Hyla staufferi* Cope have been recorded at five localities in four Mexican states. The station data are as follows: *Chiapas*, 9 miles southwest of Cintalapa, in tropical thorn forest; June 17, 1958, by Axtell. *Oaxaca*, 1 mile south southwest of Cintalapa, in tropical thorn forest; June 17, 1958, by Axtell. *Oaxaca*, 1 mile southwest of Tehuantepec, in tropical thorn forest; June 18,

1958, by Axtell; 69.1 miles south of Acayucan; July 3, 1959, by Fouquette and Collins. *Tamaulipas*, 12 miles south of Cd. Monte, elev. 325 feet; June 13, 1959, by Fouquette and Collins. *Veracruz*, 3.1 miles east southeast of Cordoba, elev. 2600 feet; June 23, 1959, by Fouquette and Collins.

The calls of this species (Table 1; Fig. 1) closely fit the pattern of the *eximia* group, although it was not included in that group on morphological grounds by Taylor (1938) or Smith and Taylor (1948). Kellogg (1932) compared this species with *eximia* and concluded that the two were probably distinct. The calls are very similar to those of fast-calling *eximia* in duration and pulse rate. They differ from the calls of that species in having a higher dominant frequency (Table 1). The three individuals from the Cordoba, Veracruz, station showed no rise in dominant frequency during the course of the call. A similar situation has been found in *H. squirella* (Table 2).

DISCUSSION

If similarity in structure of the mating call is taken as evidence of evolutionary relationship, then the *Hyla eximia* group of Taylor (1948) requires some revision, of which one interesting feature is the enlargement to include an additional U. S. species. The only species allocated to the group by Taylor that departs markedly from the basic call structure of the group, among those for which such evidence is available, is *Hyla euphorbiacea*. The call structure of this species is so different as to cast doubts on its affinity with this group.

Hyla squirella of the southeastern United States has the distinctive pattern of call structure of the *eximia* group (Table 2) and is the only frog of that area that does have it. Blair (1959) noted the similarity of call structure between *H. squirella* and *H. regilla* of the far west and used the term *squirella* group for these species. In view of the affinity of these species with *H. eximia* it seems best to use Taylor's term *eximia* group for the whole complex. The center of distribution of the *eximia* group is clearly in southern Mexico on the evidence of the several species that occur there today. The peripheral species, *H. squirella* in the southeastern United States, *H. wrightorum* at higher elevations in Arizona northward to the Colorado Plateau, and *H. regilla* of the Pacific coastal strip, all could have attained their present distributions during some wetter stage of the Pleistocene. All are presently disjunct from the main area of distribution of the group.

The closeness of relationship of *H. wrightorum* to *H. eximia* remains to be determined. Schmidt (1953) arbitrarily listed *wrightorum* as a

subspecies of *eximia*. Such treatment was premature and apparently incorrect. As we have shown, there are two call types, probably representing cryptic species in respect to morphological characters, confused under the name *H. eximia*. The call of *wrightorum* is close to that of the fast-calling *eximia*, which has not been found near the type locality for that species. The slow-calling type, which has been found in the general area of the type locality, will presumably bear the name *eximia*. Aside from this nomenclatorial problem, better biological evidence is needed before *wrightorum* is lumped with fast-calling *eximia*, whatever the name of that population will prove to be. If the fast-calling "*eximia*" from Michoacan and *H. wrightorum* should prove conspecific, the name of the latter would presumably apply unless a senior synonym could be proved.

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THE SHORT-TAILED SHREW, BLARINA BREVICAUDA, IN OKLAHOMA

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ABSTRACT. Two subspecies of the short-tailed shrew, *Blarina brevicauda carolinensis* and *Blarina brevicauda hulophaga*, have been reported from Oklahoma. Study of Oklahoman specimens reveals that all are referable to a single subspecies, *B. b. carolinensis*, with the later-named *B. b. hulophaga* as a synonym. Clinal variation in *Blarina brevicauda* in Oklahoma and several surrounding states is discussed, and records of the species in Oklahoma are summarized.

Few specimens of the short-tailed shrew, *Blarina brevicauda*, are on record from Oklahoma. Those reported have been assigned to the subspecies *B. b. carolinensis* or to *B. b. hulophaga*. Shrews from the Arbuckle Mountains have been referred to *hulophaga*, type locality east of Dougherty, in Murray County, Oklahoma, whereas shrews from elsewhere in the state usually have been referred to *carolinensis*, type locality in eastern South Carolina (see Blair, 1939:99, and Hall and Kelson, 1959:53–54).

Assignment of Oklahoman specimens of *Blarina* to subspecies has been mainly on the basis of color; those from the Arbuckle Mountains are allegedly paler. Blair *(loc. cit.)*, for example, remarked concerning *hulophaga:* "This race is known from only 4 specimens, all of which agree in being paler and more brownish in color than the race *carolinensis*. In size and cranial characters it does not differ appreciably from *carolinensis*. It seems likely that this is a slight local race, developed through partial isolation in the Arbuckle Mountains." We have seen three of the four specimens mentioned by Blair (lectotype not seen) and five specimens from Platt National Park, Murray County, all of which, considering age and season of capture, can be matched exactly in color by specimens from other parts of Oklahoma and also by specimens from Kansas and southern Nebraska. In accordance with Blair, we find no significant differences in size between specimens from the Arbuckles and those from elsewhere in Oklahoma, nor do we discern any other differences between these shrews. We conclude, therefore, that they represent one subspecies.

Color of pelage serves in part to distinguish some subspecies of *Blarina brevicauda* but, although some geographic variation undoubtedly occurs, differences in color are at best subtle in this species and are subject to variation depending on age and season. Post-mortem changes in color, those resulting from different methods of preparation of specimens, and those resulting from different storage facilities, probably also complicate the picture. Size, on the other hand, definitely varies geographically and seems to be a more useful criterion in taxonomic studies. A cline exists (subject to some local reversals) from small size in the southern populations of the species to larger size in the more northerly populations. To the west of the Mississippi River this cline is clearly evident, beginning on the Gulf Coast with the small subspecies, *B. b. minima*, and proceeding northward to *B. b. brevicauda*, the largest subspecies of the species, in central and northern Nebraska and adjacent areas to the north and east. Specimens from Oklahoma, Kansas, and southern Nebraska form the middle part of the cline (see Fig. 1 and table of measurements). Although there is an increase in both external and cranial size (we regard the latter as more significant than the former because cranial dimensions can be the more accurately measured) to the northward within the middle portion of the cline, no distinct break occurs. A significant break does occur between shrews in southern Nebraska and those in central Nebraska and it is at this break that *B. b. brevicauda* is distinguished from specimens to the south. Shrews from southern Oklahoma to southern Nebraska seem to form a more or less natural grouping within the cline and in our judgment the same subspecific name should be applied to all of them.

In the original description of *B. b. hulophaga*, Elliot (1899:287) characterized it as: "Similar to B. b. carolinensis, but lighter in color, and differing in the characters of the teeth, and in having an extremely short tail." Specimens of *Blarina* from Oklahoma, Kansas and southern Nebraska do average slightly paler than a series of *carolinensis* from Gray's Hill, Beaufort County, South Carolina, and from other specimens that we have seen from the southeastern United States, but some individuals from Oklahoma, Kansas, and Nebraska closely match those from farther east. The western shrews are larger, including length of tail, than specimens from South Carolina but north-south clinal variation in size occurs within the range of *carolinensis* as currently understood and shrews from Cambridge, Dorchester County, Maryland, referred to *carolinensis* by Bole and Moulthrop (1942:108), also are larger than Carolinian specimens (see Jones and Findley, 1954: 211, for measurements) and are of approximately the same size as a series from Richardson County, Nebraska (see measurements herein). We

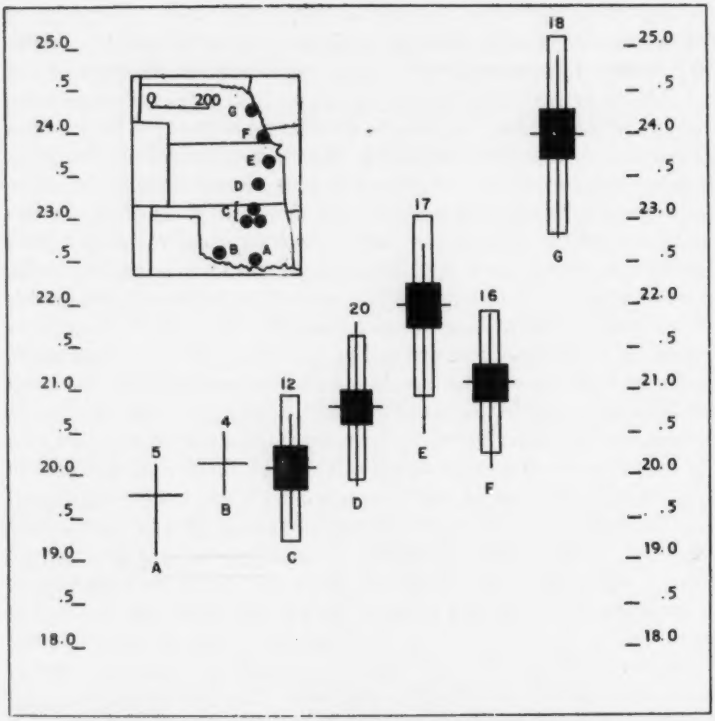

Fig. 1. Variation in condylobasal length of *Blarina brevicauda* from Oklahoma, Kansas, and Nebraska. Vertical and horizontal lines represent observed range and mean, respectively. Solid and open rectangles represent two standard errors and two standard deviations on either side of the mean, respectively. Letters below each sample indicate geographic origin (see inset). Numbers above each sample indicate size of sample.

note no peculiarities of the teeth, save larger size, in the western shrews. As a matter of fact, the several cranial and dental characters listed by Elliot *(loc. cit.)* are essentially a mixture of those that characterize the genus and those that are individually variable or that change with age.

As we noted, the subspecific name *carolinensis* is currently applied to some Oklahoman shrews. It is in current use also for shrews from Kansas and southern Nebraska, for shrews to the south of Oklahoma in eastern Texas (McCarley, 1959:393), and for shrews to the east of Oklahoma (see Hall and Kelson, 1959:53–54). We provisionally assign all Oklahoman specimens to *Blarina brevicauda carolinensis*, with the later-named *Blarina brevicauda hulophaga* as a synonym.

TABLE 1

External and cranial measurements (in millimeters) of Blarina brevicauda. *Cranial measurements were taken as described by Findley (1955:5); all specimens are age-groups 3–6 of Pearson (1945:536).*

Catalogue number or number of specimens averaged, and sex	Total length	Length of tail vertebrae	Length of hind foot	Condylobasal length	Cranial breadth	Maxillary breadth	Interorbital breadth	Length of maxillary tooth-row
Blarina brevicauda carolinensis, Gray's Hill, Beaufort Co., South Carolina								
Average 11 (6♂,5♀)	95.6	17.6	11.6	18.8	10.2	6.6	5.1	7.1
Minimum	89	15	11	18.5	10.0	6.2	4.9	6.8
Maximum	103	20.5	12	19.2	10.5	6.8	5.3	7.3
Platt National Park, Murray County, Oklahoma								
79846 KU, ♀	99	19	13.5	19.1	10.8	7.0	5.1	7.2
79847 KU, ♀	101	19	13	19.7	10.7	7.3	5.5	7.4
79848 KU, ♀	106	23	13.5	19.7	11.0	7.2	5.5	7.5
79849 KU, ♀	105	21	13	20.2	11.1	7.2	5.5	7.6
79850 KU, ♂	102+	19+	13	20.2	11.2	7.1	5.7	7.5
Wichita Mountain Wildlife Refuge, Comanche Co., Oklahoma								
3351 WMWR, ♀	106	26	15	20.1	11.1	7.3	5.4	7.8
55 WMWR, ♂	102	24	13	20.5	11.2	7.2	5.7	8.1
709 WMWR, ♂	112	19	12	20.2	11.1	7.1	5.6	7.5
Redland, Sequoyah Co., Oklahoma								
87454 USNM, ♀	117	22	15	.....	.....	7.5	5.7	8.3
87455 USNM, ♀	109	24	14	21.2	11.3	7.4	5.7	8.1
North-central Oklahoma (Creek, Osage and Payne counties)								
Average 13 (4♂,7♀,2?)	96.8	20.0	12.1	20.1	11.0	7.1	5.4	7.8
Minimum	90	17	9	19.4	10.3	6.8	5.2	7.6
Maximum	107	24	14	20.7	11.5	7.4	5.7	8.0
vicinity Hamilton, Greenwood Co., Kansas								
Average 20 (6♂,14♀)	103.6	21.2	13.4	20.8	11.3	7.4	5.6	8.0
Minimum	93	15	12	19.9	10.7	7.0	5.4	7.4
Maximum	113	25	15	21.8	11.8	7.8	5.9	8.5
Douglas Co., Kansas								
Average 17 (6♂,11♀)	110.9	23.2	14.9	22.0	12.2	7.9	5.9	8.7
Minimum	94	18	13	20.5	11.3	7.7	5.7	8.0
Maximum	121	25	18	22.7	12.9	8.2	6.2	9.0
Richardson Co., Nebraska								
Average 16 (5♂,10♀,	111.6	22.4	14.4	21.1	11.5	7.6	5.7	8.2
Minimum 1?)	103	19	13	20.1	11.0	7.3	5.5	8.0
Maximum	121	24	16	21.9	12.2	7.9	5.9	8.5
Blarina brevicauda brevicauda, vicinity Blair, Washington Co., Nebraska								
Average 18 (11♂,7♀)	132.4	26.4	17.0	24.0	13.5	8.7	6.3	9.3
Minimum	125	23	16	22.8	12.8	8.2	5.9	8.9
Maximum	141	31	18	24.9	14.0	9.1	6.5	9.7

The genus *Blarina* is in need of revisionary study. When such a study is made, we visualize that it may be necessary to restrict the name *carolinensis* to the small, uniformly dark-colored populations of the species *brevicauda* that occur along (and inland some distance from) the southern Atlantic and Gulf coasts. In this event the name *hulophaga* would be available for shrews from at least southern Oklahoma to southern Nebraska.

As mentioned, few short-tailed shrews have been reported from Oklahoma. Probably this is owing primarily to inadequate collecting but the species may actually be uncommon in some places within its range in the state. For example, McCarley (1952) took no specimens in 3535 trap nights in Bryan County in 1949–50. The known western limit of range of the species in Oklahoma is the woodland-grassland ecotone, which transects the central part of the state from north to south. Suitable habitat for the short-tailed shrew is restricted in this area.

Altogether, we have examined 53 specimens from Oklahoma and these, along with localities reported in the literature from which we have not seen specimens, are listed below. Localities in italics are not shown on the accompanying map (Fig. 2).

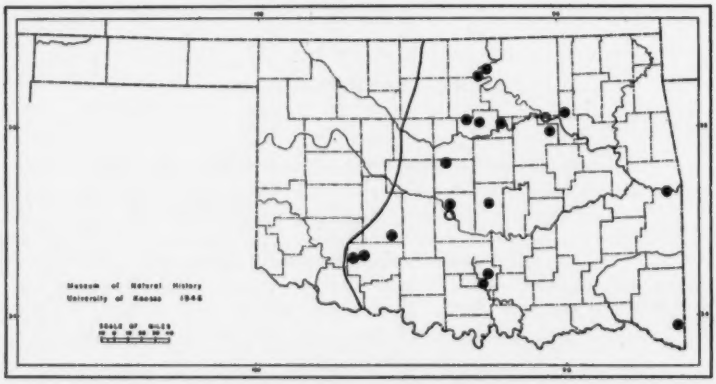

Fig. 2. Geographic distribution of *Blarina brevicauda carolinensis* in Oklahoma. Solid symbols indicate specimens examined; open symbols indicate records from the literature. The heavy line indicates the probable western margin of geographic range of the species in Oklahoma.

CADDO COUNTY: Kiowa Agency, 17 mi. SE Old Fort Cobb, 1 (USNM). CLEVELAND COUNTY: 3.2 mi. N Norman, 1 (USNM); *Norman*, 7 (6 KU, 1 OU); *4 mi. S Norman*, 1 (OU); *5 mi. S Norman*, 1 (OU). COMANCHE COUNTY: Headquarters, Wichita Mtn. Wildlife Re-

fuge, 1 (WMWR); *Camp Bolder, Wichita Mtn. Wildlife Refuge*, 1 (OSU); *½ mi. E Cozy Cove, Wichita Mtn. Wildlife Refuge*, 1 (WMWR); *Wichita Mtn. Wildlife Refuge*, 3 (1 USNM, 2 WMWR); top of Elk Mtn., Wichita Mtn. Wildlife Refuge, 1 (WMWR). CREEK COUNTY: Sapulpa, 3 (KU). KAY COUNTY: Mouth Salt Fork River, 1 (OSU). MCCLAIN COUNTY: 7 mi. S Norman (Blair, 1939:99). MCCURTAIN COUNTY: 6 mi. SE Eagleton, 1 (OSU). MURRAY COUNTY: Platt National Park, 5 (KU); *near Travertine Creek, Sulphur*, 1 (OSU); *Arbuckle Mountains*, 1 (CM); east of Dougherty, 1 (CNHM). OKLAHOMA COUNTY: 3 mi. N Edmond, 1 (CSC). OSAGE COUNTY: 3 mi. E Arkansas River bridge at Ponca City, 1 (OSU); *Conway Springs* (Blair, 1939:99). PAYNE COUNTY: SE ¼, Sec. 18, T. 19 N, R. 1 E, 9 mi. W Stillwater, 1 (OSU); *Lake Carl Blackwell, 7 mi. W Stillwater*, 2 (OSU); *3 mi. W Stillwater*, 1 (OSU); *Stillwater*, 2 (OSU); *2½ mi. S Stillwater*, 3 (OSU); 3 mi. S Stillwater, 1 (OSU); 2 mi. W Yale, 1 (OSU). POTTAWATOMIE COUNTY: Tecumseh, 2 (KU); *no specific locality*, 1 (OBU). SEQUOYAH COUNTY: Redland, 2 (USNM). TULSA COUNTY: Mohawk Park, 4 (3 UMMZ, 1 OSU); near Wekiwa (Blair, 1938:495).

We are grateful to the following persons for the loan of specimens in their care: Dr. J. K. Doutt, Carnegie Museum (CM); Dr. Ethel Derrick, Central State College, Edmond, Oklahoma (CSC); Dr. Sheridan Lee, Oklahoma Baptist University, Shawnee, Oklahoma (OBU); Dr. Robert D. Burns, University of Oklahoma Museum (OU); Dr. W. H. Burt, University of Michigan Museum of Zoology (UMMZ); and Mr. Julian Howard, Refuge Manager, Wichita Mtn. Wildlife Refuge, Cache, Oklahoma (WMWR). We are grateful also to Mr. Philip Hershkovitz, Chicago Natural History Museum (CNHM), and to Dr. David H. Johnson, U. S. National Museum (USNM), for allowing one of us (Jones) to examine specimens there. In addition, specimens in the Museum of Natural History, The University of Kansas (KU), and in the collection of Oklahoma State University (OSU) have been used. A research grant from the Society of Sigmi Xi helped to defray the cost of visiting the museums mentioned.

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GASTROPODA OF THE ROB AND BESSIE WELDER WILDLIFE FOUNDATION REFUGE, SAN PATRICIO COUNTY, TEXAS*

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ABSTRACT. The Rob and Bessie Welder Wildlife Foundation Refuge is located in the Gulf Coastal area of south-central Texas. A collection of 20,000 molluscan specimens from this refuge was found to represent 13 families, 25 genera and 35 species of Gastropoda and one family, one genus and one species of Pelecypoda. The range of *Pilsbryna tridens* Morrison is extended from Palo Pinto County and Planorbina gracilentus (Gould) from Hays County, Texas. *Gyraulus arizonsis* (Pilsbry and Ferriss) is reported from Texas for the first time. The fauna is a composite of both tropical and northern forms. The tropical element is composed mostly of species in the family Planorbidae. A key to the species collected and an annotated list are presented.

DESCRIPTION OF THE REFUGE AND COLLECTING SITES

The Rob and Bessie Welder Wildlife Refuge, under the direction of Dr. Clarence Cottam, is located in the south-central Texas Coastal-prairie Region of San Patricio County, about ten miles northeast of Sinton. The physical and biological characteristics of the area make it somewhat academic as to whether it should be placed in the Tamaulipan Biotic Province or the Texan Province (Blair, 1950). The elevation varies from 0 to over 40 feet above sea level. The soils are variable, but approximately three-fifths are made up of a black silty-clay (Victorian Clay); the remaining two-fifths are composed of silt-laden sand of the Aransas River flood plain.

The flora is typical of the subtropical Gulf coastal plains and is a function of precipitation which is only slightly in excess of the physiological requirements for the plants. Some of the cover consists of typical prairie types with incursions of *Acacia*, *Condalia*, Huisache and Mesquite. There are several species of trees along the margins of the Aransas River, such as hackberry, pecan, mulberry, elm, and a few live oaks occur on the higher ground. The east end of the refuge is only about four and one-half miles from salt water and is often subjected to increased salinity. In this area euryhaline plants (*Spartina*, *Boriccia*, etc.) are common.

The boundaries of the refuge are delimited on the north by the

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meandering channel of the Aransas River, from which they extend seven miles east to west. The east border is only about five miles from Copano Bay. (Personal communications from Dr. Cottam, 27:III:1958 and 28:II:1958).

The following are sites from which Dr. Cottam and his assistants collected large numbers of mollusks in January, 1959. Mr. Robert Downing, Oklahoma State University Wildlife Unit, also collected additional material from and around several of the same locations and from additional ones in January of 1958.

COLLECTING SITES

Station One—"Mare Trap" at the east end of the refuge grounds, on the Aransas flood plain. Large quantities of drift material taken. *Station Two*—"Yegua Tank" in the Mare Trap. This is actually a *Spartina* marsh. *Spartina*, *Boriccia*, *Lycium* and *Buchloe*. Water normally fresh but on occasion suffers increased salinity as a result of brackish overflow. *Station Three*—The highest ground in the Mare Trap, consisting of dry, sandy soil; covered by grasses and annual weeds. *Station Four*—Windmill pond of the Mare Trap. Fresh water of moderate salinity; typical marginal plants. *Station Five*—Rincon Bend of Aransas River. A low area in the flood plain consistently possessing the most saline water on the foundation grounds. *Station Six*—La Vuelta Island. This is a small island formed by a recent flood which eroded a channel across a peninsula extending into the river. *Phragmites* common. *Station Seven*—Near the water's edge on La Vuelta Island. *Station Eight*—"Venado Tank." A sand-loam area of mixed grasses and annuals. *Station Nine*—"Moody Pasture." An upland area of dry sand-loam. Many scattered live oaks. *Station Ten*—Moody Creek flood plain. Dry, calicheous sand and some Victorian Clay; occasionally inundated. Oaks, huisache and some mesquite. *Station Eleven*—Moody Pasture. Trees form a dense canopy; hackberry, elm, huisache, *Celtis* and *Acacia*. Sometimes inundated by the Aransas River. *Station Twelve*—Lake Pasture. Actually a composite collection from this area of blackland and Victorian Clay. Mixed grasses, *Celtis* and some cacti.

These collections contained nearly 20,000 specimens representing 14 families, 26 genera and 36 species. With the exception of a few examples deposited in the U.S. National Museum, the specimens were retained by the author.

ACKNOWLEDGMENTS

I am grateful to Dr. Clarence Cottam and Mr. Robert Downing for their kindness in making collections, especially to the former who sup-

plied valuable data concerning the region. Further gratitude is expressed to Dr. J. P. E. Morrison of the U.S. National Museum for verifying some of my identifications and for diagnosing some difficult species.

KEY TO THE GASTROPOD SPECIES OF THE WELDER WILDLIFE REFUGE

The following is a key to the gastropod species herein reported, including a few species which were not found but which may be expected in the refuge area. This key is doubtless not inclusive but may serve interested individuals for identification of most of the forms.

1. Shell with an operculum; whorls shouldered and often bearing spine-like processes; aperture ovate 2
   Operculum lacking; whorls, if shouldered, not bearing spines; aperture variable, if ovate, whorls not shouldered 4
2. Shell strongly shouldered; shoulders bearing spines ..... *Pyrgophorous spinosus*
   Shoulders lacking spines 3
3. Spire very short (much shorter than body whorl); shoulders rounded ..... *Amnicola peracuta*
   Spire about as long as body whorl; shoulders blunt ..... *Texadina sphinctostoma*
4. Shell sinistral ..... *Physa anatina*
   Shell dextral 5
5. Shell patelliform (hat-like, widely open below) ..... *Ferrissia*
   Shell with whorls 6
6. Shell much higher than wide; possessing many whorls 7
   Shell not much higher than wide; whorls few if spire everted 16
7. No teeth within aperture; shell strongly tapering; lip thickened, sub-ovate and white; shell 3 to 6 mm. long ..... *Pupoides albilabris*
   One to several teeth in or near aperture 8
8. A single small tooth near the basal columellar lip; shell minute (1.5 to 1.7 mm. long x 0.6 mm. diam.); shell glistening white; eyes near base of posterior tentacles ..... *Carychium exile*
   More than one tooth in aperture; shell not glistening white; eyes at tips of posterior tentacles 9
9. Outer lip with a dip in the middle and a groove behind it; shell

small, ovate, cinnamon-colored and glossy 10
Outer lip evenly rounded or straight 11

10. Five or more teeth in aperture ..... *Vertigo ovata*
Three teeth in aperture ..... *Vertigo oscariana*

11. Aperture nearly filled with large teeth ..... *Gastrocopta contracta*
Aperture more capacious; teeth smaller 12

12. Shell ovate, or oblong-ovate; not cylindric 13
Shell cylindric to cylindric-tapering; not ovate 14

13. Aperture with 6 or 7 teeth; 1.7 to 2.0 mm. long ..... *Gastrocopta tappaniana*
Aperture usually with 5 teeth (sometimes 6 or 7); 1.5 to 1.8 mm. long ..... *Gastrocopta pentodon*

14. Shell less than 1.0 mm. in diameter ..... *Gastrocopta pellucida*
Shell diameter 1.0 mm. or more 15

15. Parietal tooth strongly bifurcated in frontal view; crest behind lip, if present, weakly developed ..... *Gastrocopta procera*
Parietal tooth straight or sinuous, not at all bifurcate; a strong crest behind the lip ..... *Gastrocopta cristata*

16. Shell dome-shaped and moderately to strongly ribbed; teeth (lamellae) within the aperture; lip thickened 17
Shell not both dome-shaped and ribbed 18

17. Shell finely ribbed; height about ½ the diameter ..... *Strobilops hubbardi*
Shell coarsely ribbed; height much more than ½ the diameter ..... *Strobilops labyrinthica*

18. Shell with a strongly everted spire 19
Shell with spire depressed or only moderately everted 27

19. Shell marked by brownish and grayish streaks and blotches; relatively large shells 20
Shell not so marked 21

20. With a blunt projection from base of columella; shell thickened ..... *Bulimulus alternatus*
Columella smooth; shell thin ..... *Bulimulus dealbatus*

21. Median jaw strongly trilobed; eyes at tips of posterior tentacles; whorls of shell not shouldered 22
Median jaw not trilobed; eyes at base of posterior tentacles; shell whorls shouldered 26

22. Penis bearing a well-developed sheath and lacking an appendix near its middle 23

Penis without a sheath but bearing a large appendix near its middle.....*Quickella vermeta*

23. Columella twisted.....*Succinea grosvenori*
Columella evenly arched..... 24

24. Adult shell small (8 to 9 mm. length).....*Succinea unicolor*
Adult shell larger (9.5 to 17 mm. length)..... 25

25. Shell rather thick, whitish outside, yellowish within; mantle yellowish-brown.....*Succinea luteola*
Shell thin, amber-colored on outside and within; mantle black, flecked with lighter shades.....*Succinea concordialis*

26. First laterals of radula bicuspid; shell whorls 6 or 7; growth lines coarse.....*Lymnaea bulimoides*
First laterals tricuspid; shell whorls 4½ to 5½; growth lines usually fine.....*Lymnaea humilis*

27. Spire whorls depressed below others; eyes at base of posterior tentacles 28
Spire whorls not depressed below others; eyes at tips of posterior tentacles 36

28. Shell sinistral.....*Helisoma trivolvis*
Shell dextral..... 29

29. Umbilicus deep and vortex-shaped; a strong keel above and below the periphery; aperture bell-shaped.....*Helisoma anceps*
Umbilicus shallow; strong keels lacking; aperture not bell-shaped 30

30. Base of body whorl very flattened; shell very thin; aperture flattened on one side.....*Drepanotrema cultratum*
Base of body whorl not strongly flattened; aperture usually evenly rounded..... 31

31. Diameter of shell 6.0 mm. or less..... 32
Diameter of shell usually greater than 6.0 mm..... 34

32. Surface of shell bearing conspicuous spiral striae.....*Gyraulus arizonensis*
Conspicuous striae lacking..... 33

33. Aperture loop-shaped.....*Gyraulus parvus*
Aperture nearly round.....*Gyraulus circumstriatus*

34. Aperture bearing teeth (may be far within).....*Planorbina obstructus*
Aperture lacking teeth..... 35

35. Last whorl slightly carinate on periphery; aperture nearly round; color glistening white in life....*Planorbina gracilentus*
Last whorl with a rounded periphery; aperture somewhat

loop-shaped; pale horn-colored in life....*Planorbina orbiculus*

36. Lip reflected; diameter 7.0 mm. or more; three teeth in aperture, or if teeth are lacking shell variously banded and marked 37

Lip not reflected; diameter less than 7.0 mm..... 41

37. Aperture toothless; shell grayish or often banded with white .....*Praticolella berlandieriana*

Aperture with three teeth..... 38

38. Parietal lip raised above the whorl before it.....
.....*Polygyra auriformis*

Parietal lip adnate to preceding whorl..... 39

39. A distinct groove in the last whorl paralleling the umbilical suture; diameter usually 8.0 mm. or less....*Polygyra mooreana*

No distinct groove paralleling umbilical suture; diameter usually 8.5 mm. or more..... 40

40. Lip teeth separated by a V-shaped, narrow notch.....
.....*Polygyra triodontoides*

Lip teeth separated by a U-shaped, wide notch.....
.....*Polygyra triodontoides*

41. Shell surface dull, coarsely ribbed or very flattened..... 42

Shell surface polished, never coarsely ribbed; usually with a low conoid spire..... 46

42. Shell brownish in color; spire low; diameter greater than 3.5 mm.; no teeth in aperture.....*Thysanophora horni*

Lacking this combination of characters (shell not brownish in color, or if it is, of less than 2.0 mm. in diameter; diameter of less than 3.0 mm. or if greater than 3.0 mm. then there are usually teeth present far back in the aperture and the shell is spirally striate and has a flat spire)..... 43

43. Shell with conspicuous spiral striae; two teeth usually present within the aperture; diameter greater than 3.0 mm.....
.....*Helicodiscus eigenmanni*

Shell not spirally striate; no teeth in aperture; diameter 3.0 mm. or less..... 44

44. Shell with evenly-spaced, raised growth lines; diameter usually less than 1.5 mm.....*Punctum virteum*

Shell nearly smooth; diameter usually 1.5 mm. or more..... 45

45. Diameter greater than 2.0 mm.; umbilicus more than 2½ times in greatest diameter.....*Helicodiscus singleyanus*

Diameter less than 2.0 mm.; umbilicus less than 2½ times in greatest diameter.....*Helicodiscus nummus*

46. Shell with a high conoid spire; whorls 6 or slightly more; um-

bilicus lacking.....*Euconulus chersinus*
Shell with a low spire; whorls less than 6; umbilicate..... 47

47. Aperture bearing three teeth (may usually be seen through the shell); diameter 1.4 to 1.6 mm.....*Pilsbryna tridens*
Aperture lacking teeth..... 48

48. Diameter of shell 4.5 to 6.0 mm..... 49
Diameter of shell less than 3.0 mm..... 50

49. Umbilicus minute (25 to 30 times in diameter of shell); whorls bearing distinct impressed radial lines.....*Retinella indentata*
Umbilicus larger (4½ to 5 times in diameter of shell); impressed radial lines lacking.....*Zonitoides arboreus*

50. Sculpture of oblique lines crossed by fine spiral striae; adult shell minute (1.6 to 1.8 mm. in diameter); umbilicus less than ⅓ the diameter of shell.....*Striatura meridionalis*
Sculpture of unevenly distributed growth lines; spiral striae lacking; adult shell 2.0 to 2.5 mm. in diameter; umbilicus ⅓ or more the diameter of shell.....*Hawaiia minuscula*

ANNOTATED LIST

PELECYPODA

Mytiliopsis leucophaeata (Conrad)

Collections: Stations 1, 6 and 7. This species was the only pelecypod collected. A total of 312 specimens were taken, many of them attached to stems of *Phragmites communis*. The clam was particularly abundant at station 7. According to Pennak (1953) this pelecypod's range extends from Maryland to Florida but not into Texas.

Although this single pelecypod species was the only one found in the collections others may doubtless be found in the refuge waters. *Rangia cuneata* Gray is a common species in certain areas near San Patricio County.

GASTROPODA

PROSOBRANCHIA

With the exception of a single species the members of this subclass were of low incidence in the collections.

Family Oligyridae

Oligyra orbiculata tropica (Pfeiffer)

Collections: At all stations and from many additional sites by Mr. Downing.

Hundreds of typical specimens of this species, which is the only terrestrial operculated form in the area, were taken. The only vari-

ation noted was that of color. The shell and operculum ranged from pure white, through a pastel pink to a light brown.

Family Amnicolidae

Amnicola (Cincinnatia) peracuta (Pilsbry and Walker)

Collections: Stations 1 and 6. A total of seven shells, two of which were immature, was collected.

Pyrgophorous spinosus (Call and Pilsbry)

Collections: Stations 1 and 6. Sixteen shells of this peculiar snail were found, mostly at station 6. This species is easily recognized by the rows of acuminate spines on the shoulder of the whorls.

Texadina sphinctostoma Abbott and Ladd

Collections: Stations 1 and 6. A single immature shell was found in river debris from station 6; three immature shells were taken at 1.

It will be noted that the last three species were all found at stations 1 and 6, which are subject to periodic increased salinity. The last two species can thrive in quite brackish water and can be used as indices to such conditions.

PULMONATA

All aquatic forms discussed below belong to the order Basommatophora. The terrestrial species, with the exception of those in the genus *Carychium*, are in the Stylommatophora.

Order *Stylommatophora*

Family Polygyridae

Two genera and two species were in the collections but there is a strong possibility that at least three others occur on the refuge grounds. These three species, which have been included in the preceding key are: *P. auriformis* (Biand), *P. mooreana* (Binney) and *P. triodontoides* (Bland).

Polygyra texasiana (Moricand)

Collections: Stations 1, 8, 5, 6, 2, 4, 10 and 11. A total of 1132 specimens were collected. Thirty-eight specimens, or 3.4% of the total, exhibit abnormalities of the apertural armature. The brief table below shows the type and distribution of these anomalies.

Specimens	*Type of Anomaly*
2	Parietal tooth lacking; lip teeth much reduced
2	All teeth lacking
20	All teeth much reduced
2	Parietal tooth much reduced; lip teeth lacking
10	No parietal; lip teeth normal
2	Normal parietal; lip teeth much reduced

Several of the anomalous shells look quite like *Polygyra triodontoides* and the shells erroneously recorded from Texas as this species by T. D. A. Cockerell (Pilsbry and Ferriss, 1906) were probably based upon such shells. However, these shells are easily distinguished from *P. triodontoides* by the single orange-brown band just below the periphery. The only other banded *Polygyra* in the United States is *Polygyra scintilla* Pilsbry and Hubrich (1956).

Praticolella berlanderiana pachyloma

Collections: Stations 1, 2, 5, 6, 7, 10 and 11. Twenty-four specimens were taken by Downing; 168 were found at station 1 and 10 to 15 shells were taken from each of the other collecting sites. All specimens seem to be typical.

Family Sagidae

A single species represents this family, which is closely related to the Polygyridae, in this area. Many species are known from Mexico and Central America.

Thysanophora horni (Gabb)

Collections: Stations 1 and 6. Downing found nine shells, all of which had the periostracum eroded away. A total of seven specimens was found by the other collectors. *T. incurstata* (Poey), not included in the key, is known from Galveston (Pilsbry, 1948) and should be sought.

Family Bulimulidae

During the hot months of the year these large terrestrial snails aestivate on the stems of plants in most parts of the Texan Biotic Province. However, the author has never seen many aestivating individuals in Oklahoma, possibly due to a more humid condition of the soil. Several hundred specimens of two species were collected from the refuge.

Bulimulus dealbatus mooreanus (Pfeiffer)

Collections: Stations 1, 4, 5, 8, 9, 10, 11 and 12. Forty-four shells were taken from Downing's collections and several hundred from the other sites. About 10% of them seem to be intergrades with *B. d. ragsdalei*.

Bulimulus alternatus mariae (Albers)

Collections: Stations 1, 5, 9 and 11. The 148 shells collected were characteristic of this subspecies.

Family Zonitidae

This family is second only to the Pupillidae, in species and numbers, in this area. Evaluation of the collected material disclosed six species in six genera.

Euconulus chersinus (Say)

Collections: Stations 1 and 6. This species is rather scarce as only four specimens were found in the entire collection.

Retinella indentata paucilirata (Morelet)

Collections: Stations 1, 6 and 10. A total of 39 typical specimens were found.

Pilsbryna tridens Morrison

Collections: Stations 1 and 6. Twenty-three of these minute shells were collected, six by Downing and 17 by the other collectors. The species was previously known only from Palo Pinto County in northern Texas and from several localities in Oklahoma. These records extend the known range southward by about 300 miles.

Hawaiia minuscula (Binney)

Collections: Stations 1 and 6. About 1080 specimens were collected. All are typical *H. minuscula*, but it would not be surprising if *H. m. neomexicana* (Cockerell) is present on the refuge.

Zonitoides arboreus (Say)

Collections: Station 1. Only four specimens of this ubiquitious species were taken.

Striatura meridionalis (Pilsbry and Ferriss)

Collections: None. Although this species was not collected it doubtless occurs on the refuge. The type locality is near New Braunfels, Hays County (Pilsbry and Ferriss, 1906), which is only 125 miles from the refuge.

Family Endodontidae

Eighteen specimens, two species of a single genus, were collected.

Helicodiscus eigenmanni (Pilsbry)

Collections: None.

The author found this species abundant in several localities surrounding San Patricio County. Consequently, it should be expected on the refuge.

Helicodiscus singleyanus (Pilsbry)

Collections: Stations 1 and 6. The 13 specimens taken from the above localities are members of a subgenus in *Helicodiscus* (with the next species) which are minute, smooth and edentate. Care should be exercised not to confuse these two species with *Hawaiia.*

Helicodiscus nummus (Vanatta)

Collections: Stations 1 and 6. Downing collected a single specimen of this minute snail; Dr. Cottam took four. This species was supposed by Pilsbry and Ferriss (1906) to be restricted to the Lower So-

noran biotype but has since been found in several localities in the more humid Sonoran.

Punctum vitreum H. B. Baker

Collections: None. Although this species was not collected it has been found in several counties north of San Patricio. The type came from San Marcos (Pilsbry, 1948).

Family Succineidae

Only one genus and species was collected.

Succinea luteola Gould

Collections: Stations 1, 2, 6, 10 and 11. Apparently this is the only common succineid snail in the area. Downing collected 17 specimens and a total of 37 shells were in the other collections.

The possibility of other species occurring in this part of Texas is good, but they will probably be found in small numbers. Some of these are: *Succinea unicolor* Tryon (reported from Galveston); *S. grosvenori* Lea (north-central Texas); and *S. concordialis* Gould (Comal, San Marcos).

Quickella vermeta (Say)

Collections: None. This species has long been known as *Succinea avara* (Say) but Hubricht (1958) places it in the above genus. Pilsbry (1948) records the species for all of Texas. Consequently it is to be expected on the refuge grounds.

Family Strobilopsidae

A single species was collected but a second may confidently be expected.

Strobilops labyrinthica (Say)

Collections: Stations 1, 6 and banks of Aransas River, near Moody Pasture. Downing found a single immature specimen; 32 perfect shells were taken by Dr. Cottam and his assistants from the other localities. This is a dome-shaped species with nodose internal lamellae. Pilsbry (1948) records this species widely distributed in several of the states west of the Mississippi.

Strobilops hubbardi Brown

Collections: None. The Texas form of this plains species is to be expected near the bases of trees and on grassed slopes.

Family Pupillidae

The Pupillidae is the second richest family as regards numbers and the largest terrestrial taxon present. Two genera and six species were found in the collections.

Genus *Gastrocopta*

As far as species are concerned this is the largest single taxon herein reported. In the plains region large (15–20,000 specimens) col-

lections of terrestrial gastropods are often composed of 80 or more per cent of a mixture of *Gastrocopta* and *Hawaiia*. In the present series five species were observed.

Gastrocopta contracta (Say)

Collections: Stations 1 and 6. Forty-two perfect shells and several broken ones were collected. Most fit best the characters given by Pilsbry (1948) for the subspecies *G. c. climeana* (Vanatta).

Gastrocopta pentodon (Say)

Collections: Station 1. Three shells were found. This is the most widely distributed gastrocoptid in the United States and probably occurs under the live oaks and other trees.

Gastrocopta tappaniana (Adams)

Collections: Stations 1 and 6. The 200 specimens found are typical. This species frequents the lowlands and usually occurs under fallen bark, decaying wood and similar substances.

Gastrocopta procera (Gould)

Collections: Stations 1 and 6. Six of the 18 shells taken by Downing appear to be typical *G. procera*. This percentage was not maintained in the nearly 500 shells taken by the other collectors. Nearly all of these specimens possess characters which align them with the subspecies *G. p. sterkiana* Pilsbry. Only about 10% approach the typical subspecies.

Gastrocopta cristata (Pilsbry and Vanatta)

Collections: None. Although no specimens were collected at the refuge, this species has been recorded from as far west as Laredo (Pilsbry, 1948) and doubtless occurs in San Patricio County.

Gastrocopta pellucida hordeacella (Pilsbry)

Collections: Stations 1, 6, 12, Pollito Lake and Calaboose Pasture. Approximately 500 specimens of this widespread species were taken. All seem to be of the *hordeacella* type.

Genus *Pupoides*

Members of this genus are among the largest of the pupillid gastropods. A single species is reported.

Pupoides albilabris (Adams)

Collections: Stations 1, 6, 9, 12 and Mesquite Tank. Two hundred typical shells were found.

Genus *Vertigo*

No specimens of this genus were collected. However, two species may occur in the area.

Vertigo oscarina Sterki

Collections: None. I have collected a few specimens of this

species from several localities west of Austin (Comal, San Marcos and in the hills near San Marcos).

Vertigo ovata Say

Collections: None. It is especially probable that this form will be found on the refuge as Ferriss and Pilsbry (1906) described a new subspecies, *V. o. diaboli* Pilsbry, from near the Devil's River, Val Verde County. Since this subspecies has been collected in Oklahoma on several occasions it surely occurs in the intervening region.

Basommatophora

These pulmoniferous forms have sessile eyes near the bases of the posterior tentacles. One terrestrial species occurs in the area, but it was not collected at the refuge. However, thousands of specimens representing six genera and eleven species of aquatic pulmonates were found.

Family Carychiidae

This monogeneric family is probably represented by a single species.

Carychium exile Lea

Collections: None. This easily-recognized species is the one mentioned above as a terrestrial member of this order. Since it is minute and fragile, it is often overlooked while collecting.

Family Lymnaeidae

Although several species in this taxon are abundant in more northern areas only a single species appears to be numerous here. Following Hubendick (1951) all of the species in the family, with one exception, are placed in the genus *Lymnaea.*

Lymnaea bulimoides techella Haldeman

Collections: Stations 1 and 6. A total of 27 specimens were collected, three by Downing. As pointed out by Hubendick (Op. Cit.) there is probably no reason to recognize the infraspecific epithet.

Lymnaea humilis Say

Collections: None. The presence of this form is especially probable since the synonymy of this species includes several names which have been used for specimens collected in Texas (*L. parva* Lea; *L. obrussa* Say; *L. modicella* Say; *L. dalli* Baker; etc.). Cheatum (1935) reports the *L. parva* and *L. dalli* forms in western Texas.

Family Planorbidae

The members of this family, as is usual in the Texan and Kansas biotic provinces, make up a large percentage of the freshwater fauna. In the present work five genera and nine species are reported.

Genus *Planorbina*

The three species herein reported are relatively rare in the

United States, and belong to a group which is mostly tropical and subtropical. (Paraense and Deslandes, 1957).

Planorbina obstructus (Morelet)

Collections: Stations 1 and 6. This species and the next are very abundant in certain areas of the refuge. Downing collected over 500 shells and nearly twice this many were taken by the others. The species is easily separable from the next two by the three teeth within the aperture.

Planorbina orbiculus (Morelet)

Collections: Stations 1, 2 and 11. As with the last-named species, Downing collected nearly 500 specimens in the Mare Trap. Dr. Cottam took 22 shells at station 11 and over 1100 from stations 1 and 2.

Planorbina gracilentus (Gould)

Collections: Station 10. This species, which is apparently rather common near San Marcos (Baker, 1945), is probably quite rare in San Patricio County as only a single specimen was found.

Genus *Drepanotrema*

This is another essentially Neotropical genus (Paraense and Deslandes, 1956), the northern-most limit of which is in Bastrop County, Texas, on the south bank of the Rio Colorado (Pilsbry, 1934).

Drepanotrema cultratum labrosum Pilsbry

Collections: Stations 1 and 2. A total of over 2500 shells of this distinctive species were collected from 1 (Mare Trap) but only 47 at station 2. The type locality for this subspecies is Brownsville and it is the only form that occurs in Texas. There is a rather strong callus just inside the lip and the singularly depressed, horn-colored shell bears a keel on its edge. The specimens ranged in size from less than 0.5 mm. to nearly 7.0 mm. and the number of whorls varied from slightly over 2 to 5½.

Genus *Gyraulus*

Three species were collected which belong to this genus, which is mainly Holarctic in distribution.

Gyraulus circumstriatus (Tryon)

Collections: Station 6. Only six specimens were taken but it is probably more common than this indicates. I have found this small planorb abundant in Zilker Park, Austin.

Gyraulus parvus (Say)

Collections: Station 6. As with the above species only a few shells (7) were found, but the species is probably more abundant than these scanty records indicate.

Gyraulus arizonensis (Pilsbry and Ferriss)

Collections: Stations 1 and 6. This interesting species was very abundant at the "mare trap," where Downing took 91 specimens, and three shells were collected at station 6. The author compared these shells with specimens of *Gyraulus arizonensis* collected near the type locality of the species and found the two lots to be indistinguishable (Branson, in press). As seen in the above key, the shell is peculiarly marked by strongly raised spiral striae (spiral lines) and may be confused for some small planorbids inhabiting the West Indies. The shells varied from 1.1 mm. to 3.2 mm. in diameter and the number of whorls from two to two and two-thirds. These characteristics will immediately distinguish the species from any other on the refuge.

Gyraulus arizonensis is a much more widely distributed species than its authors supposed. The records herein recorded extend the range from the type locality, the San Pedro River, near Benson, Arizona, by approximately 800 air miles. Furthermore, a collecting party from Oklahoma State University, consisting of the author, Mr. C. J. McCoy and Mr. M. E. Sisk, found several specimens of the small snail at the mouth of the Rio Yaqui in Sonora, Mexico.

Genus *Helisoma*

Two extremely wide-spread species were collected. One was very abundant, the other was represented by a single specimen.

Helisoma anceps Menke

Collections: Station 9. A single shell was found which may have washed in from the Aransas River. *H. anceps* appears to be numerous in the Rio Guadalupe in Comal County, but seems to be progressively more scarce as one approaches the subtropical region of San Patricio County.

Helisoma trivolivis lentum (Say)

Collections: Stations 1, 2, 6, 10, 11 and several other small bodies of water. About 600 specimens were found by both collecting parties. This is the subspecies characteristic of the region and when found at all, it is usually abundant. Cheatum (1935, 1939) finds this to be true in the Davis Mountains and in Wharton and Harris counties. Specimens from Austin appear to be intergrades with the subspecies *H. t. intertextum* (Sowerby), whereas Baker (1945) finds that shells taken near Leon, Texas are pure *H. t. intertextum*.

Family Physidae

All of the specimens collected from the refuge are referable to one species.

Physa anatina Lea

Collections: Stations 1 and 10. The center of distribution for

this gastropod lies in Oklahoma and southern Kansas (Branson, in press) and thespecies is less abundant towards the Gulf of Mexico. Cheatum (1939) records this species from Nueces, Wharton and Kendall counties and from Brazoria County (as *P. forsheyi*). It is also abundant near Austin (Branson, unpublished) and in the Davis Mountains (Cheatum, 1935). Approximately 60 specimens were taken from the refuge.

Family Ancylidae

Although no ancylids were found in these collections, members of the genus *Ferrissia* are to be expected in the waters of the region. However, one should guard against mistaking the valves of some very large ostracods, *Chlamydotheca unispinosa* (Baird), which frequent the area for *Ferrissia*. These ostracods were found in large numbers in the Mare Trap.

CONCLUSIONS

The species composition of this subtropical region is obviously of diverse origin; the tropical district being represented mainly by planorbid species and the Holarctic by zonitids, polygyrids and pupillids. This, then, is a meeting ground for southern and northern species and should be vigorously explored, especially west of the refuge along the coast, to more fully understand the fauna of this little-known region. The range of *Gyraulus arizonsensis* should be worked cut and other tropical species sought.

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NEW SPECIES OF THE QUINARIA GROUP OF DROSOPHILA (DIPTERA, DROSOPHILIDAE)

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ABSTRACT. The widespread American species called "*transversa*" is shown to be undescribed, while the Rocky Mountain species, *subquinaria* Spencer, agrees in most respects with the European *transversa*. Three new species of this complex are described: *Drosophila falleni* from Ontario to Florida to Texas to Minnesota; *recens* from North Dakota to Maine and Ontario; and *rellima* from Nebraska, Oregon and California.

The European species *Drosophila transversa* Fallén was first reported from North America by Loew (1864), and later authors have continued to use this name for a common species of the eastern United States. Hsu (1949) pointed out, however, that the male genitalia of American specimens differed from that of "*transversa*" from Switzerland and from China.

In reinvestigating this problem I have had the loan of additional material from the U. S. National Museum, through the assistance of Dr. W. W. Wirth, and from the Canadian National Collection, through the assistance of Dr. J. F. McAlpine. In addition, Mr. E. B. Basden of Edinburgh, Scotland, has most generously supplied specimens, drawings, photographs and copious notes on true European *transversa*, including data on the lectotype and syntypes from Fallén's collection.

It is now clear that the widespread American species going under the name *transversa* is quite distinct; it is described below as *Drosophila falleni* in honor of the famous dipterist who established the genus *Drosophila* in 1823.

Examination of the male genitalia of some American members of the quinaria species group revealed, however, that *Drosophila subquinaria* Spencer is extremely similar to the true *transversa*; hybridization tests between them will be carried out in the near future to confirm or deny this possible synonymy.

During this study two additional new species of the quinaria group were discovered; these are described below as *D. recens* and *rellima*. Holotypes of the new species are in the Drosophila Type and Reference Collection of the University of Texas, Austin. Some paratypes

of each species are being placed in the U. S. National Museum collection and in the Canadian National Collection.

Drosophila subquinaria Spencer

1942. Univ. Texas Publ. 4213:59.

The original cultures of this species were collected by Gordon Mainland and the writer at Manitou Springs and Estes Park, Colorado, Yellowstone and Grand Teton Parks, Wyoming, and Cottonwood Canyon, Utah. It was later reported from Sierra Blanca, New Mexico, by Patterson (1943). The holotype has been lost (Warren P. Spencer, personal communication).

The abdominal pattern of an average female, from Utah, is shown in Figure 3, and the shape of the inner sclerotized capsule of the spermatheca is shown in Figure 7. Figure 11 illustrates the dorsal view of the tip of the aedeagus; the superimposed dotted line represents a thin shelf of the hypandrium which is quite obvious, and distinctive, in slide preparations of the aedeagus-hypandrium complex. The shape of this shelf is the most satisfactory means of separating males of *subquinaria* and *recens* (Fig. 10). (The illustration of the genital arch and clasper of *subquinaria* in Hsu, 1949, based on specimens from North Dakota, does not belong to this species but to *recens*.)

Males with this type of aedeagal structure have come from Wyoming (Daniels), Utah (Duchesne), Oregon (Gold Beach), Ontario (Sault Ste. Marie), British Columbia (Mummery Flat, Robson, and Trinity Valley), and Alaska (widespread). Confirmation of the presence of this species in other reported localities is not possible at present due to the lack of male specimens.

Males of the European *transversa* can usually be distinguished from *subquinaria* by the shape of the "hypandrial shelf" (shown on a reduced scale as Figure 11b), but occasional specimens of both "species" are more or less intermediate.

Drosophila falleni, new species

I am giving this name to the American species which has incorrectly been called *transversa* Fallén for nearly a century. The internal and external features have been described (under the name *transversa*) by Patterson (1943) who also figured the female in color. The geographical distribution was summarized by Patterson and Wagner (1943) and the chromosomes were described by Wharton (1943). The figure of the external male genitalia in Hsu (1949), however, was

based upon true *transversa* from Switzerland using specimens sent to us by Dr. Hans Burla of Zurich.

The abdominal pattern of an average female is shown in Figure 1; the spots are noticeably weaker than those of *transversa* or *subquinaria* and tend to become fainter on posterior segments so that in some individuals, none is seen on the sixth segment. Figure 5 shows the shape of the capsule of the spermatheca and Figure 9 illustrates the tip of the aedeagus which is quite distinct from that of the other members of the species complex. We have checked males from Ontario, Quebec, Massachusetts, New Hampshire, Connecticut, Maryland, Virginia, District of Columbia, Tennessee, Missouri, Ohio, Wisconsin, Minnesota, Colorado, Alabama, Texas, and a single, unexpected, specimen from Robson, British Columbia.

Holotype male and 9 paratypes from Dexter, Missouri collected in August 1948 by the writer; 10 paratypes from Great Smoky Mountain National Park, Tennessee.

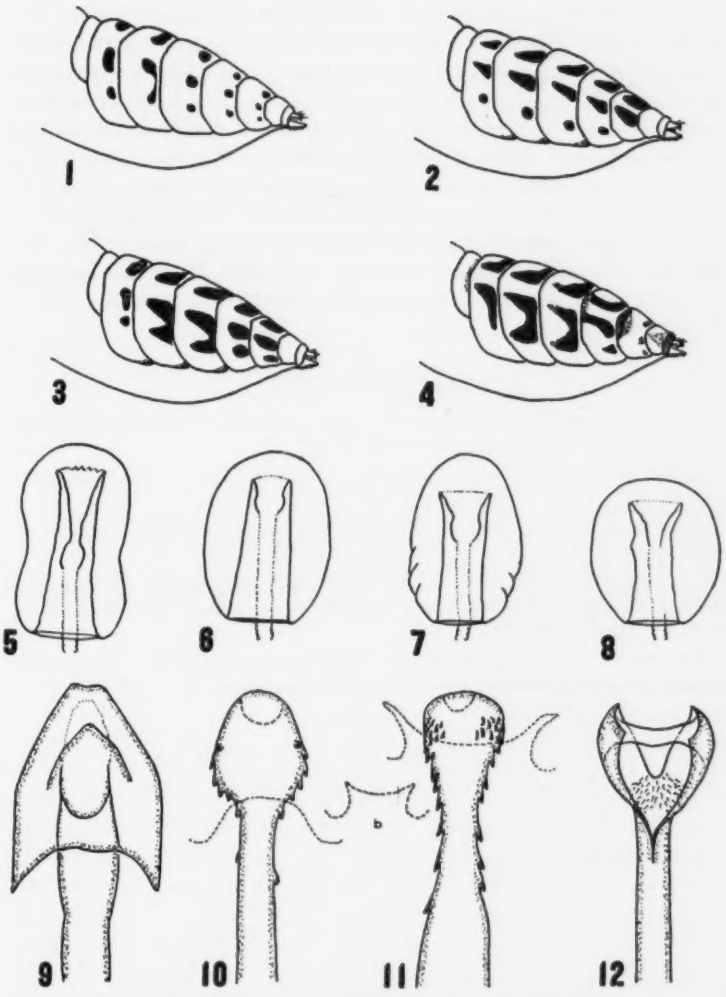
Drosophila **recens,** new species

The abdominal pattern of an average female (from Maine) is shown in Figure 2; as in all members of this species complex some variation in pattern occurs. In contrast to *falleni*, with which it is sometimes sympatric, the more posterior segments show a stronger, darker pattern. *D. recens* is probably sympatric in the west with *subquinaria*; the most useful differences between them are found in the genitalia. Figure 6 shows the shape of the capsule of the spermatheca, and the tip of the aedeagus is shown in Figure 10. The distal end is larger than in *subquinaria*, the "dull barbs" are fewer, and the shelf of the hypandrium (dotted line) is of a different shape. Males agreeing in this genitalial pattern have come from North Dakota, Michigan, Maine, Ontario and Quebec. We suspect that the species is relatively common in the New England area and extends westward across the northern states to North Dakota. The genital arch and clasper were described by Hsu (1949), under the name *subquinaria*, using material from Lake Irvine, North Dakota.

Holotype male and 3 paratypes from Houghton Lake State Forest, 30 miles north of Clare, Clare Co., Michigan, collected in August 1948 by the writer; 9 paratypes from Mt. Desert Island, Maine.

Drosophila **rellima,** new species

This new species can usually be separated from *subquinaria* by its darker pigmentation. The abdominal pattern of a female from Nebraska is shown in Figure 4; the pattern on specimens from Oregon



Figs. 1–4, Female abdominal patterns of four species of *Drosophila*, shown in dorsolateral view. Figs. 5–8, Inner sclerotized capsule of spermathecae. Figs. 9–12, Distal portion of aedeagus.

Figs. 1, 5, 9, *D. falleni*; Figs. 2, 6, 10, *D. recens*; Figs. 3, 7, 11, *D. subquinaria*; Figs. 4, 8, 12, *D. rellima*. The "shelf of the hypandrium" is shown in dotted outline on Figs. 10 and 11, the inset (Fig. 11b) representing, on a reduced scale, the shape of the shelf in typical European *transversa*.

and California is not quite so extensive. The mesonotum usually shows some darkening between and on each side of the dorsocentral bristles, the latter thus appearing to lie on a lighter line. The disc of the scutellum is typically darkened, the pleura shows some darker discoloration, and the sixth segment of the male abdomen is usually heavily darkened, showing very little or no pale interruption of the band medianly.

The capsule of the spermatheca is shown in Figure 8, and the distinctive tip of the aedeagus, which is somewhat like that of *magnaquinaria*, is shown in Figure 12. Males with this type of genital structure have been identified from Oakdale, Nebraska, Gold Beach, Oregan, and Montebello (near Pasadena), California. Holotype male and 11 paratypes from Oakdale, Nebraska, collected in August 1950 by the writer.

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POPULATION FLUCTUATION IN THE AMPHIBIAN FAUNA OF CLEVELAND COUNTY, OKLAHOMA DURING THE PAST TWENTY-FIVE YEARS

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ABSTRACT. Fluctuation in numbers of Amphibia of some (but not of other) species in Central Oklahoma has been noted. Some declines have been correlated with human activity, whereas others have not. Two species of *Pseudacris* tend to replace one another according as periods of light and heavy rainfall occur locally. Some species have essentially maintained their numbers regardless of environmental fluctuations.

Each year since 1935, I have watched the amphibians of Cleveland County, Oklahoma by taking frequent local trips over the county during nights of amphibian breeding, and daylight trips to examine breeding sites and to collect and study eggs and tadpoles. Through this, voluminous notes on various species have accumulated along with notes on weather conditions, use of each of many breeding sites from year to year and physical changes in these.

Fifteen forms are represented in the county (Bragg 1942), two of them salamanders, the remainder frogs and toads. These are distributed ecologically (see map in Bragg, 1940b) some showing much more restriction than others (Bragg, 1940, 1940a, 1943, 1943a, 1950, 1950a). The following forms have shown no marked fluctuation in population or distribution in this area during the period under consideration, essentially 1935–1959: (1) *Ambystoma texanum* Matthes; (2) *A. tigrinum mavortium* Baird; (3) *Acris gryllus blanchardi* Harper; (4) *Microhyla carolinensis olivacea* (Hollowell); (5) *Pseuacris strekeri strekeri* Wright and Wright; (6) *Rana pipiens berlandieri* Baird; (7) *Rana catesbeiana* Shaw; (8) *Scaphiopus bombifrons* Cope; and (9) *S. holbrooki hurteri* Strecker. The remainder have done so as discussed below.

(1) *Bufo cognatus* Say. As indicated by Bragg and Weese (1950), this species often fails to reproduce successfully during some years due to chance distribution of rainfall. Sometimes two or three years pass with no metamorphosed young produced locally. Nevertheless, in earlier years whenever breeding conditions were right, enormous numbers

of calling males were about pools, thus indicating a large population of adults (Bragg, 1940; Bragg and Smith, 1943). This was true, for example in 1935, 1938, and 1941, all good breeding years. But in 1957, a year of very heavy spring rainfall and therefore an excellent breeding year, only small congresses could be found (Bragg and Brooks, 1958) and no adults were seen during that summer. In 1958 a single small breeding congress was seen locally containing not more than fifteen or twenty individuals; and a thorough search during two nights after rains in May and early June, 1959 indicated only a small population of breeding adults to the west of Norman where large congresses used to occur, although thousands of young had been produced there in 1957. Either the young of the 1957 season had mostly been killed off, had migrated, or had not reached sexual maturity. Fair sized congresses occurred in late June in the eastern and central parts of Norman, however, but still not nearly as large as might have been expected. One of these successfully produced young.

Concerning the first of the above possibilities, thousands were known to have been killed on roads by autos in 1957 and many others maimed in various degrees by farm machinery working the fields. But it seems quite unlikely that the majority of so vast a number as noted (Bragg and Brooks, 1958) should have been so affected. Concerning possible migration, local mass directional movements were not evident in the young toads in 1957 (Bragg and Brooks, 1958) and these juveniles continued to be locally abundant into the early fall. Yet, the following spring and summer (1958) few could be found and as I write this (mid-September, 1959) not a single one of 1500 marked juveniles of the 1957 season has been seen in the region of their release. If many were present and if males became sexually mature in two years as thought probable by Bragg and Weese (1950), one would have expected large congresses in 1959.

(2) *Bufo terrestris charlesmithi* Bragg. In the early years of this study, the dwarf American toad occurred very abundantly in the region of its type locality, but later all but disappeared (Bragg 1954). In 1955, two juveniles were found and during the next two years one or two calling males in a place could occasionally be heard. By 1957, during a rainy spring, a dozen or so males sometimes called at some pools during good breeding nights and many tadpoles were produced for the first time since the decline in numbers. In 1958 and 1959, the numbers about pools (calling males) were comparable to the original condition, indicating a nearly complete recovery in population size.

(3) *Bufo woodhousei woodhousei* Girard. Despite an earlier decline in numbers in and about Norman (Bragg, 1954), the population on

the Canadian River flood plain has remained stable. In 1958, a few were found also in the oak-hickory savannah east of Norman for the first time in several years. This toad while subject to minor fluctuations locally, seems able to maintain a fairly stable population in Cleveland County, Oklahoma, as a whole.

(4) *Hyla versicolor*. The population here has been interpreted as intergrades between *H. v. versicolor* LeConte and *H. v. chrysoscelis* Cope (Bragg, 1958). During the drouth years of 1954 through 1956, only once and in one place did this form call in anything like its former abundance. This suggested that the population in general may have declined sharply. This was confirmed in 1957 during the phenomenally heavy rains, in and after which only very small congresses and no tadpoles were seen in pools usually containing them in abundance. There seemed to be plenty of adults in the 1958 breeding periods, however, which may indicate a sudden buildup to normal numbers again in one year of successful breeding, as also happened with *B. cognatus* (Bragg and Brooks, 1958). Breeding congresses in spring, 1959, were of normal size.

(5) *Pseudacris*. Three forms occur locally; *P. clarki* Baird typically in the prairie, *P. n. triseriata* (Wied) mostly in the savannah, and *P. streckeri streckeri* Wright and Wright, unrestricted. *Pseudacris clarki* has been more or less like *B. cognatus* but it maintained its numbers better because it seems somewhat more adjustable in its breeding pattern. Both forms are xeric but it takes a smaller amount of rain (sometimes as little as ⅓ inch) to stimulate *Pseudacris* to breeding activity. Also, it is not so greatly inhibited by low temperatures. *Pseudacris s. streckeri* has maintained its population here at a high level, regardless of conditions during the last 20 years, at least. It is a purely winter and early spring breeder and typically its tadpoles are well developed before most other species start reproducing. Therefore, even in relatively dry years its breeding is little affected. In dry winters, however, it does not breed in any numbers and in some places not at all as in 1958–59.

P. n. triseriata has had an interesting history. In 1938 (a wet spring), several small breeding congresses were seen in the prairie near Norman, but none has been found there again. In 1941 and again the following spring, they appeared in small numbers in the western edge of the oak-hickory savannah. By 1945, they were quite abundant there, and thereafter for several years they could always be heard on breeding nights from almost every pool of the proper type. Then, I could find none at all for several years and neither their eggs nor tadpoles in dozens of pools examined. This remained true in 1957 (during

heavy rains) but they reappeared (in small numbers) in 1958 and I found more in 1959. Simultaneously, with their decline, *P. clarki* extended its range eastward into the savannah where it was formerly known only from "islands" of prairie in the more locally xeric areas. In both 1958 and 1959 they bred in pools where *P. n. triseriata* were formerly abundant but now absent. In this ecotonal region, it seems that these two forms vary in numbers locally depending upon cyclic changes in rainfall. Wet years (or a series of them) favor the expansion to the westward of the savannah form (*triseriata*); dry years, the eastward expansion of the prairie form (*clarki*). In the past 25 years, I have witnessed such fluctuations twice. This observation explains the apparent discrepancy in the observations of Smith (1935), who found *P. clarki* in wooded regions in Central Oklahoma and of Bragg (1943) who called this a form of the grassland. Both reports are correct for the seasons involved.

(6) *Microhyla carolinensis olivacea.* This form, with its xeric breeding pattern, might be expected, *a priori*, to behave about as *B. cognatus* and *P. clarki*, but it has not done so. Its population in the Norman area has remained approximately constant and apparently materially unaffected by environmental changes of all types. Breeding congresses in 1957 were as large as in earlier years, despite three previous drouth years; and in 1958, despite this exceptionally favorable breeding year (i.e., 1957) were no larger than usual. Its success is attributed at least in part to the following factors: (1) small amount of stimulation necessary to initiate breeding; (2) a very fast rate of tadpole development, due in part to the probable effect of high temperatures, but almost certainly partly inherent; (3) the secretive behavior of adults and (4) protective secretions of the adult skin which may cut down predation loss.

DISCUSSION

As implied above, one major factor in the whole situation is the wet-dry cycle in this region with population shifts in some species but not in others. But another factor applicable immediately about Norman is interference by man. Some species are known to be especially prevalent about the edges of stabilized cities and villages (Walker, 1946). With the rapid growth of the City of Norman beginning with World War II and accelerated since then, stabilized breeding sites for many forms have been progressively and extensively destroyed. Four places where prior to 1941 enormous numbers of *B. cognatus* bred after each rain of consequence in spring or summer are now typical residential areas of the city. In addition, increased human population has increased auto traffic to such an extent locally, that literally hundreds

of thousands of *Bufo* and of *Scaphiopus bombifrons* are killed along the highways, especially after rains. When the city reaches its expansion limit, one of these human factors will lessen in severity but the other will not. Perhaps then dozens of large female toads will sit about the lights on the University of Oklahoma campus on summer nights, feeding, as they did prior to 1940. It has been several years now since I have seen a toad on the campus.

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NOTES

NEW COMBINATIONS IN TEXAS EUPHORBIAS OF SUBGENUS CHAMAESYCE.—The following new combinations are needed in writing a treatment of the Euphorbiaceae of western Texas and in compiling a checklist of the family for F. W. Gould's revised edition of V. L. Cory's and H. B. Parks' Catalogue of the Flora of the State of Texas 1st ed., Texas Agric. Expt. Sta. Bull. No. 550, 1938.

Euphorbia missurica Raf. var. **calcicola** (Shinners) new comb. based on *Chamaesyce missurica* var. *calcicola* Shinners, Field & Lab. 17: 69, 1949.

Euphorbia perennans (Shinners) new comb. based on *Chamaesyce perennans* Shinners, Field & Lab. 24: 38, 1956.

Euphorbia simulans (L. C. Wheeler) new comb. based on *Euphorbia polycarpa* var. *simulans* L. C. Wheeler, Rhodora 43: 192, 1941.—*Barton H. Warnock, Sul Ross State College, Alpine, Texas, and Marshall C. Johnston, The University of Texas, Austin, Texas.*

RANUNCULUS TRILOBUS (RANUNCULACEAE) IN SOUTHERN LOUISIANA: NEW TO THE UNITED STATES.—In Lyman Benson's "A Treatise on the North American Ranunculi" (Amer. Midl. Nat. 40: 113–114, 1948), the Mediterranean annual *Ranunculus trilobus* Desf. is reported as casual in Bermuda. No other records are given in his "Supplement" (l.c. 52: 328–369, 1954). The species can now be reported from south central LOUISIANA, Pointe Coupee Parish: 8 miles east of Livonia, *Shinners 28,145*, 17 April 1960 (SMU; dupl. POM). A number of plants were found in dried-up mud in a roadway leading from the main highway south over the adjacent railroad tracks. The manner of their introduction is entirely unknown. They were growing vigorously and seeding freely, so that its further spread seems likely.—*Lloyd H. Shinners, Southern Methodist University, Dallas 22, Texas.*

A NEW SPECIES OF HIBISCUS FROM TEXAS.[1]—During a survey for host plants of the pink bollworm, *Pectinophora gossypiella* (Saud.), an important economic insect of cotton, a new species of *Hibiscus* was found in Orange County, Texas. The description of this plant is as follows. This work was done in cooperation with the Texas Agricultural Experiment Station.

Hibiscus leucophyllus Shiller, sp. nov.

Radix perennis, succulenta; caules usque ad 8 dm. alti, sursum paullo ramosi, dense puberuli, pilis minutis, ulti-ramosis, sessilibus stellatis; folia numerosa, petiolata, petiolo usque ad 4 cm. longo, dense pubrulo; laminae foliorum anguste ovatae, usque ad 14 cm. longae et 6 cm. latae, basi rotundatae vel majores subcordatae, apice acriter longe acuminatae, grosse obtuseque serratae basibus et apicibus exceptis, basi 7-nervatae, nervis subtus prominulis, supra impressis, supra pallide olivaceo-virides, subtus pallidiores et cinereae, utrinque dense stellato-pubescentes, pilus superficie inferiore conspicue albidis; pedunculi axillares, 1-flori, pedicellis breviores; bracteae involucelli numerosae, lineares, liberae, calycibus multo breviores, dense tomentulosae, setis marginalibus nullis; calyx 2–2.5 cm. longus, lobis ovatis, quam tubo longioribus, externe dense stellatotomentulosis; petala 7–8 cm. longa, alba basi purpureo-maculata; capsulae breviter rostratae, 20–23 mm. longae, juventute dense

sed minute stellato-tomentosae, demum glabrescentes, sed pilis paucis in marginibus persistentibus; semina glabra.

Roots perennial, succulent; stems up to 8 dm. high, somewhat branched upwardly, densely puberulous with minute, many-branched, sessile stellate hairs; leaves numerous, petiolate, the petiole up to 4 cm. long, densely puberulous like the stems; leaf-blades narrowly ovate, up to 14 cm. long and 6 cm. wide, rounded or the larger subcordate at base, sharply long-acuminate at apex, coarsely and bluntly serrate except at very base and at apex, 7-nerved at base, the nerves raised beneath, impressed above, light olive-green above, paler and ashy beneath, densely stellate-pubescent on both sides, the hairs beneath conspicuously whitish; peduncles axillary, one-flowered, shorter than the pedicels; involucre of numerous, linear, free bractlets these much shorter than the calyces, densely tomentulose, lacking long, simple bristly hairs on the margins; calyx 2–2.5 cm. long, the lobes ovate, longer than the tube, densely stellate-tomentulose externally; petals 7–8 cm. long, white with a purple blotch at the base; capsule short-beaked, 20–23 mm. long densely and minutely stellate-tomentose when young, finally glabrescent, although with some persistent hairs along the margins of the valves; seed glabrous.

Holotype (US) Texas. Orange Co.: Mauriceville, July 15, 1958. *I. Shiller s.n.* (assigned specimen No. 2,313,322). Isotypes (US): No. 2,313,323 and 2,313,324.

This species is similar to *H. lasiocarpus* Cav. in the general characteristics of growth, however the plants of *H. leucophyllus* are smaller and the individual stems have a tendency to branch at the top making the plant bushier, more leafy and spreading, especially in open spaces. It also sheds its fruiting forms readily and the plants generally have fewer mature capsules than do those of *lasiocarpus*. The leaves are covered on both sides with very fine and dense stellate pubescence, giving the plant its conspicuous ashen color, and hence the name *leucophyllus*. It has a glabrous capsule.

H. leucophyllus differs considerably from *H. incanus* Wendl. in its characteristics of growth. The individual stems of *incanus* attain a height of over 2 meters and generally without branching at the top, while those of *H. leucophyllus* seldom attain a height of 1 meter. The leaves of *H. incanus* are subcordate at the base and acuminate and/or acute at the apex, light olive-green, glabrous or only sparsely pubescent above, distinctly paler or ashy beneath with dense stellate pubescence. The hairs beneath give the underside of the leaves a white appearance. However, the capsule of this plant is glabrescent and of about the same shape.—*Ivan Shiller, Entomology Research Division, Agr. Res. Serv., U.S.D.A.*

CROTON POTTSII, EARLIER NAME FOR C. CORYMBULOSUS.—Dr. J. E. Dandy of the British Museum of Natural History has kindly made available an excellent photograph of the type specimen of *Croton Pottsii* (Klotzsch) Muell. Arg. W. J. Potts collected it near the city of Chihuahua. It is clearly *C. corymbulosus* Engelm. var. *corymbulosus*, sensu Johnston (The Texas species of *Croton* (Euphorbiaceae), S.W. Nat. 3: 175–203, 1959). Since Klotzsch's name antedates Engelmann's by 22 years, the following new combination is needed.

Croton Pottsii var. **thermophilus** (M. C. Jnstn.) M. C. Jnstn., based on *Croton corymbulosus* var. *thermophilus* M. C. Jnstn., S.W. Nat. 3: 187, 1959.—*Marshall C. Johnston, The University of Texas, Austin.*

ORYZOMYS COUESI ONLY SUBSPECIFICALLY DIFFERENT FROM THE MARSH RICE RAT, ORYZOMYS PALUSTRIS.—*Oryzomys palustris*, having six currently recognized subspecies, as heretofore known, ranges southward from New

Jersey and southeastern Pennsylvania over the southeastern and south-central United States, to Corpus Christi Bay on the Texas coast.

Oryzomys couesi, having 12 subspecies, ranges northward from Costa Rica, in Central America, to the lower part of the Rio Grande Valley in Texas. On the coastal mainland of Texas between Corpus Christi Bay and Brownsville there is a north to south, 140-mile-long hiatus from which no rice rats have been reported on taxonomically. Nevertheless, rice rats occur in the mentioned hiatus as shown by specimens that have been accumulated in the Museum of Natural History of The University of Kansas. These specimens, mostly obtained in the spring of 1959 by Max Thompson, reveal intergradation between *Oryzomys palustris texensis* and *Oryzomys couesi aquaticus*.

In his revision of the rice rats (N. Amer. Fauna, 43:29, September 23, 1918) E. A. Goldman characterized *Oryzomys couesi* as resembling *Oryzomys "palustris*, but sphenopalative vacuities, large in that species [*O. palustris*], absent or much reduced in size; antorbital foramen with anterior border more rounded above, more inclined or produced forward at the base, not excised or tending to develop the somewhat *Sigmodon*-like point often present in *palustris;* interparietal with a more evident posterior angle." My own comparison of specimens reveals no additional cranial differences. As between *Oryzomys couesi aquaticus* from Brownsville and other parts of the Rio Grande Valley, and *Oryzomys palustris texensis* from San Patricio County, Texas, there is an appreciable difference in color of upper parts in April-taken specimens of the same age. Those of *O. c. aquaticus* are paler. Nevertheless, the color of the upper parts of the specimens from San Patricio County (Pollito Lake and Tule Lake, both on the Welder Refuge) is almost exactly intermediate between that of populations of the pale *O. couesi aquaticus* to the southwest and that of populations of the dark (not April-taken) *O. palustris texensis* from still farther east in Texas.

In 5 specimens (80533, 80535–80537, 80540 K.U.) from four and one-tenth miles west of Port Mansfield, Willacy County, Texas, the sphenopalatine slits are partly closed in 3 and open in 2; the anterior border of the antorbital foramen in all 5 is variously intermediate between the condition in *O. c. aquaticus* and *O. p. texensis;* the interparietal in 1 (80537) has an evident posterior angle and in 4 does not; the pale color is indistinguishable from that of *O. c. aquaticus*. Considering all four differential features, the series shows slightly more resemblance to *texensis* than to *aquaticus*. The same is true of four additional specimens from five and seven-tenths miles west of Port Mansfield.

In 10 specimens from fourteen and seven-tenths miles east of Brownsville, Cameron County, Texas, the sphenopalatine slits are closed in 1 (80549) and partly closed in 9; the base of the anterior border of the antorbital foramen in 3 resembles the condition in *O. palustris texensis* but in the other 7 agrees with that in *O. couesi aquaticus;* the rounded anterodorsal angle of the border in each of the 10 agrees with the condition in *O. couesi aquaticus;* the interparietal is angled in 1, semi-angled in 4, and not angled in 5. The upper parts are pale and therefore indicative of *O. couesi aquaticus*. Considering all of the differential characters, the series from fourteen and seven-tenths miles west of Brownsville shows much more resemblance to *O. couesi aquaticus*.

The structural intermediacy of the two lots of specimens just mentioned, and the geographic intermediacy of their localities of capture, clearly demonstrating intergradation between *Oryzomys palustris texensis* and *Oryzomys couesi aquaticus*, suggest that the dividing line between the two subspecies is approximately on the southern boundary of Willacy County, Texas, and give basis for arranging the

subspecies of *O. couesi* as subspecies of the species *Oryzomys palustris*, which name has 40 years priority over *Oryzomys couesi*. The currently recognized subspecies of the two nominal species, therefore, can properly stand as follows:

Oryzomys palustris albiventer Merriam, 1901, type from Ameca, 4000 ft., Jalisco.

Oryzomys palustris aquaticus J. A. Allen, 1891, type from Brownsville, Cameron Co., Texas.

Oryzomys palustris aztecus Merriam, 1901, type from Yautepec, Morelos.

Oryzomys palustris coloratus Bangs, 1898, type from Cape Sable, Monroe Co., Florida.

Oryzomys palustris couesi (Alston), 1877, type from Cobán, Guatemala.

Oryzomys palustris crinitus Merriam, 1901, type from Tlalpan, Distrito Federal México.

Oryzomys palustris lambi Burt, 1934, type from San José de Guaymas, Sonora.

Oryzomys palustris mexicanus J. A. Allen, 1897, type from Hacienda San Marcos, 3500 ft., Tonila, Jalisco.

Oryzomys palustris natator Chapman, 1893, type from Gainesville, Alachua Co., Florida.

Oryzomys palustris palustris (Harlan), 1837, type locality, "Fast Land", near Salem, Salem Co., New Jersey.

Oryzomys palustris peragrus Merriam, 1901, type from Río Verde, San Luis Potosí.

Oryzomys palustris pinicola A. Murie, 1932, type from a pine ridge, 12 mi. S El Cayo, British Honduras.

Oryzomys palustris planirostris Hamilton, 1955, type from 1 mi. W of third bridge that spans Matachla Pass, Pine Island, Lee Co., Florida.

Oryzomys palustris regillus Goldman, 1915, type from Los Reyes, Michoacán.

Oryzomys palustris richmondi Merriam, 1901, type from Escondido River, 50 mi. above Bluefields, Nicaragua.

Oryzomys palustris sanibeli Hamilton, 1955, type from 4 mi. W of lighthouse on Sanibel Island, Lee Co., Florida.

Oryzomys palustris texensis J. A. Allen, 1894, type from Rockport, Aransas Co., Texas.

Oryzomys palustris zygomaticus Merriam, 1901, type from Nentón, Guatemala. —*E. Raymond Hall, Museum of Natural History, The University of Kansas, Lawrence.*

FLAMMULATED OWL IN LUBBOCK COUNTY, TEXAS.—Early in November, 1950, Dr. M. F. Landwer, who lives just north of the city-limits of Lubbock, Lubbock County, Texas, captured alive on his place a Flammulated Owl (*Otus flammeolus*). By force-feeding the bird, he succeeded in keeping it alive for about a month. On December 7 it died. Dr. R. W. Strandtmann, of the Department of Biology of Texas Technological College in Lubbock, measured and skinned the specimen, finding the wingspread to be 17¼ inches, the ovary distinct and unpaired, the body much emaciated. The two acres about Dr. Landwer's house are thickly planted with fruit trees, vines and flowers, and the owl probably found this vegetation a haven of refuge. *Otus flammeolus* is known to be resident in the Chisos and Guadalupe Mountains of extreme southwestern Texas (A.O.U. Check-List of North American Birds, 5th edition, 1957, p. 277; Van Tyne and Sutton, 1937, *Misc. Publ. Mus. Zool. Univ. Michigan* No. 37, pp. 36–37; Wolfe, 1956, Check-List of the Birds of Texas, p. 36), but it has not, so far as I know, been reported from elsewhere in the state. The Lubbock specimen is very much grayer, i.e., less reddish

brown in general, especially about the face and on the crown and upper back, than an incubating female (GMS 8607) I collected on April 4, 1939, at an elevation of about 10,000 feet, near Las Vigas, Veracruz, Mexico. The Lubbock bird presumably represents the nominate race (wing, chord, 119 mm., primaries pressed flat, 129); it is now housed with our bird collections at the University of Oklahoma.—*George Miksch Sutton, Department of Zoology, University of Oklahoma, Norman, Oklahoma.*

PTYCHOCHEILUS LUCIUS (CYPRINIDAE) IN THE SAN JUAN RIVER, NEW MEXICO.—Hearsay reports suggesting the presence of the Colorado River squawfish, *Ptychocheilus lucius* Girard, in northwestern New Mexico (Koster, William J., 1957, *Guide to the fishes of New Mexico*. Univ. of New Mexico Press, Albuquerque, New Mexico, viii + 116 pp.) were recently confirmed by the receipt of two specimens captured by Mr. Milton Seibel of Arboles, Colorado. These are the first specimens known from the San Juan portion of the Colorado River Basin. Since little seems to be recorded for this, the largest species of North American Cyprinidae, the following notes are appended.

The first specimen, an adult male, 415 mm. standard length, was taken in June, 1959. The second, an adult female, 590 mm. standard length, was captured on August, 29, 1959 during my visit to the area. The digestive tract of the female contained parts of a half-grown sucker, *Catostomus latipinnis*. The male was empty. In life the female was silvery olive on the snout, opercle, and dorsal portion of the head and body; somewhat yellowish along the sides, especially posteriorly; and whitish on the ventral surface. The fins were pale olive suffused with pink. An orange spot, about the size of the eye, was present on each cheek and a third was present on the left side just above the vent. The iris was golden about the pupil and silvery elsewhere. The fresh-frozen male was similar except that it lacked the orange spots.

Both individuals were caught in the same pool of the San Juan River about 3 miles below the town of Rosa, Rio Arriba County, New Mexico. The pool is about 600 feet long, 100 feet wide, and between 3 and 4 feet deep. Along one side is a rocky bluff 15 to 20 feet high and along the other is a sloping, floodplain meadow. The bottom of the pool is covered with soft silt except near the upper end where sand, gravel, and rubble are exposed. The riffle just above the pool is neither as swift nor as well-defined as are most others in the area. It is about 150 feet long, 75 feet wide, 2½ feet deep, and has a strong current. The female *Ptychocheilus* was captured in moderately strong current near the end of this riffle.

Mr. Seibel, a retired gentleman who presently spends much time fishing the streams of the area, reports that salmon, as they are called by those who distinguish them from the similar, but smaller, "whitefish" (=*Gila robusta*), are usually caught by persons angling for channel catfish. Apparently, the species is not common for persistent anglers catch no more than two or three "salmon" a year. The largest caught in the area weighed twenty pounds. Because "salmon" fight so well, they are usually returned unharmed to the water so that they may fight again. "Whitefish," on the other hand, are cast on the bank. "Salmon" have been caught in the San Juan River from the Navajo Dam Site, which is just below the mouth of Los Piños River, to the mouth of Las Piedras River in extreme southern Colorado. Although all are good-sized streams, "salmon" have not been taken in Los Piños, Las Piedras, or the San Juan above its junction with Las Piedras.

At the beginning of my visit, the San Juan River was high and heavily charged with erosion silt brought in by recent rains. By the end of the week, the stream had

subsided and lost most of its load but was still turbid; transparency was about one inch. As judged by conditions when the river had nearly returned to its normal stage, this portion of the San Juan River is fairly uniform in width, about 100 feet across, with the pools somewhat wider and riffles somewhat narrower. Most pools are several hundred yards long and have a thick, soft layer of silt over a gravel bottom. The riffles are two or three feet deep most of the way across, are swift and, because the bottom is of rounded and firmly embedded gravel and rubbles, contain relatively little shelter for fish.

The fish fauna of this section of the San Juan River has not been adequately sampled, but it is known to include the flannelmouth sucker, *Catostomus latipinnis* Baird and Girard; bluehead mountain sucker, *Pantosteus delphinus* (Cope); bony-tail, *Gila robusta* Baird and Girard; dusky dace, *Rhinichthys osculus* (Girard); fathead minnow, *Pimephales promelas* (Rafinesque), channel catfish, *Ictalurus punctatus* (Rafinesque); blue catfish, *Ictalurus furcatus* (LeSueur); and the sculpin, *Cottus bairdi* Girard. Mr. Seibel reports that black bullheads and another species, whose description suggests to me *Xyrauchen texanus* (Abbott), are also taken occasionally.

The future of the *Ptychocheilus* population in the San Juan River is uncertain because Navajo Dam, now under construction, will flood the entire portion of the river from which the species has been reported.

The author wishes to thank Mr. Milton Seibel for the donation of the two specimens and for other courtesies. Thanks are also due to Dr. A. E. Dittert who, alerted for specimens, secured the first one from Mr. Seibel.—*William J. Koster, University of New Mexico, Albuquerque.*

ACORN WOODPECKER IN OKLAHOMA.—At 1:45 P.M. January 16, 1960, a single Acorn Woodpecker (*Melanerpes formicivorus*) was seen in the oak-cedar association of the headquarters area of the Wichita Mountains Wildlife Refuge, Comanche County, Oklahoma. The bird, which was observed for several minutes at a distance of less than twenty feet, was evidently an adult female as the black band between white forehead and red crown was clearly visible. A little more than two hours after this observation a sleet storm enveloped this southwestern Oklahoma location. Again, on the morning of January 27, Mrs. Halloran saw a similar Acorn Woodpecker at the same location. The senior author was nearby, saw the bird, and verified the identification. We notified Dr. George M. Sutton, University of Oklahoma, of this occurrence and he added the species to the Oklahoma list (pers. comm.). Since these observations, an acorn woodpecker has been seen twenty-four different days at the same location. The last sighting was made April 24 by James L. Norman, Muskogee, Oklahoma. It is assumed that these observations are of a single individual. A small group of the closely allied red-headed woodpeckers (*Melanerpes erythrocephalus*) have wintered in the immediate vicinity. Several times both an acorn woodpecker and a red-headed woodpecker were seen together on the same blackjack oak.

Since the above observations Dr. Sutton (pers. comm.) found that a bird in the Northwestern State College Collection, Alva, Oklahoma, identified and reported through the years as a Lewis's Woodpecker, is actually an Acorn Woodpecker. The bird, an adult, was taken in Woods County, Oklahoma in 1908 by G. W. Stevens. —*Arthur F. and Audrey G. Halloran*, Wichita Mountains Wildlife Refuge, Cache, Oklahoma.

REVIEWS

THE MAMMALS OF TEXAS. WILLIAM B. DAVIS. Texas Game and Fish Commission, Austin. 1960: Bull. No. 41, 252 pp. $0.50.

The time is past due for an authoritative handbook and checklist of the most diversified mammalian fauna of any state. This revision of an earlier popularly written pamphlet could have filled this need. Unfortunately it does not, although it is vastly improved over the earlier publication. The present publication suffers most from its apparently hasty and careless preparation. Among the more obvious examples is the discrepancy between the stated range of *Scalopus aquaticus* (p. 34) and the range map on the facing page. Surely, the reader without familiarity with the mammal literature will be puzzled by the locality record for Presidio County, when the range is given as "eastern half of the state." The discrepancy between stated range and range map is comparably bad for *Baiomys taylori* (p. 174). Careless work is further evident in the failure to list *Cryptotis parva* from the Panhandle (p. 39), although a series from Hutchinson County is catalogued in one of the collections from which the author took his records.

The extent to which the literature has been consulted is impossible to determine, since there are no standard literature references. It is obvious, however, that no effort was made to incorporate some of the readily available information; this results in some curious anomalies as in the treatment of *Procyon lotor* (p. 75). This species ranges throughout Texas, as stated on the facing page. Inclusion of literature records such as those of Goldman (1950, North Amer. Fauna No. 60) and Cutter (1959, Southwestern Naturalist 4(1): 30–34) would have made the range map more consistent with the stated distribution.

The non-professional reader will have a bad time with some of the nomenclature if he should chance to compare names with those in recent monographic treatments. He might finally figure out that *Pedomys ochrogaster* corresponds to *Pedomys ludovicianus* of Miller and Kellogg's (1955) "List of North American Recent Mammals" and *Microtus ludovicianus* of Hall and Kelson's (1959) "Mammals of North America." Little space would have been required to clarify this and similar cases for the average reader.

The species accounts include statements of "Description," "Distribution" and "Habits," and they have in them much worthwhile information. This is unquestionably the best presently available reference devoted to Texas mammals, but it is to be regretted that it is not much better. One gets the feeling that carelessness and lack of documentation are excused because the book is directed to the non-professional public, but this attitude seems indefensible. Since this is the only modern checklist of Texas mammals, it will find use in college courses in mammalogy and natural history. A few hours of annotation by one who knows the literature will make this publication reasonably adequate for such purpose. It is regrettable that such annotation could not have been included in the original publication.—*W. Frank Blair, Department of Zoology, University of Texas, Austin.*

INFORMATION FOR CONTRIBUTORS

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